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INVENTORY OF COMBUSTION-RELATED EMISSIONS FROM STATIONARY SOURCES

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Energy-Environment
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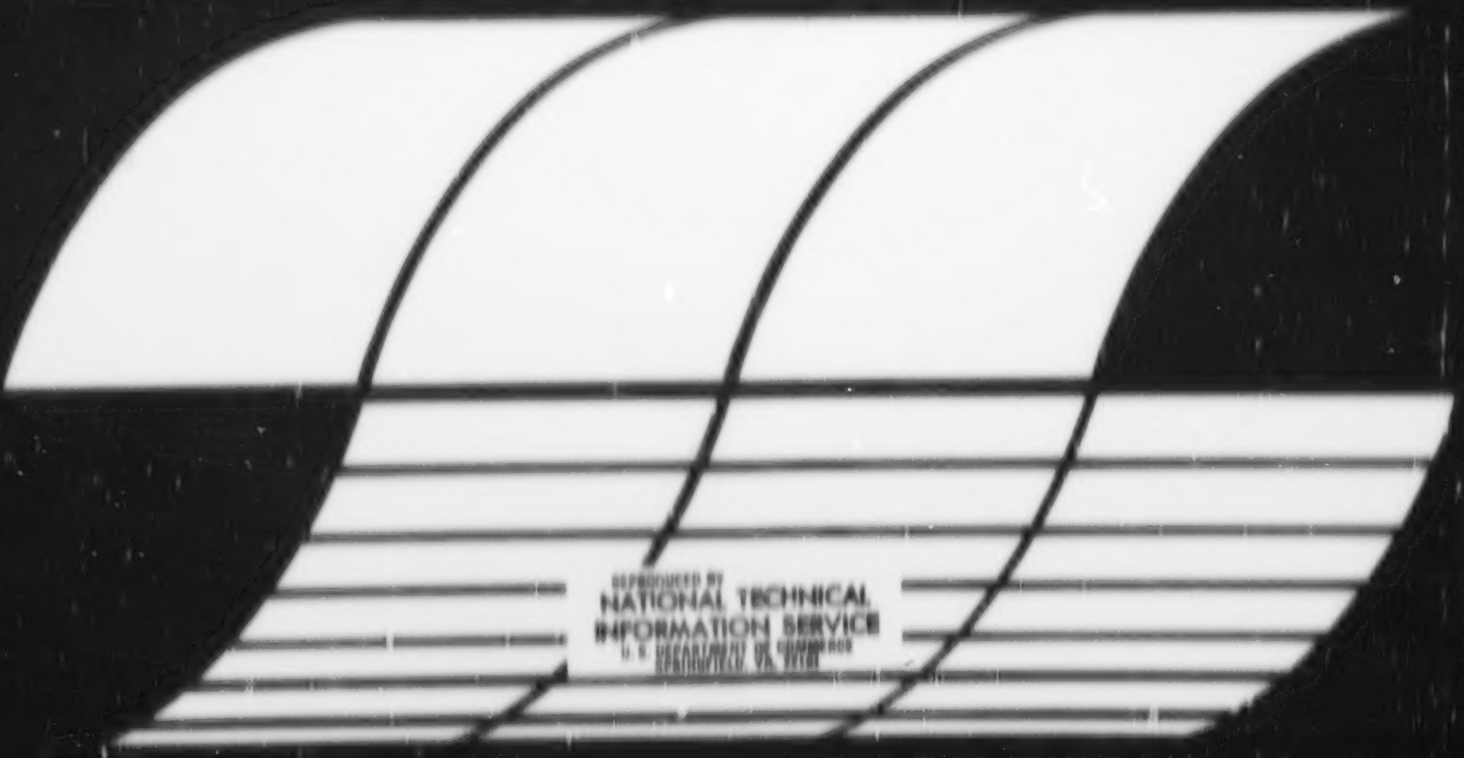
Program Report



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16. ABSTRACT
The report describes the first year of a study covering the combustion-related emissions inventory phase of a 3-year program entitled, "Analysis of NOx Control in Stationary Sources." The study is aimed at assisting in the establishment of priorities for detailed studies of techniques for the control of combustion-related emissions from stationary sources. To develop the proper perspective, it was necessary that the inventory include emissions of oxides of nitrogen, unburned hydrocarbons, carbon monoxide, and particulate, not only from recognized major stationary combustion sources, but also from other stationary source categories in which combustion plays a secondary role. During the first year of the study, emissions were established for 1975 and 1980 from boilers, internal combustion engines, chemical manufacturing, and petroleum refining. In the second year, comparative combustion-related emissions data will be obtained for selected industries including evaporation and primary metals. The third year will cover mineral products, secondary metals, and wood products. This report identifies approximately 90 percent of all nitrogen oxide emissions and from 40 to 50 percent of unburned hydrocarbons, carbon monoxide, and particulate matter for stationary sources.

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Exhaust Gases	Fuel Oil	Stationary Sources	21B	
Nitrogen Oxides	Natural Gas	Emissions Inventory	07B	
Carbon Monoxide	Boilers	Particulate		13A
Dust	Internal Combustion Engines		11G	
Hydrocarbons			07C	21G
Chemical Industry	Petroleum Refining		07A	13H

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ABSTRACT

This report describes the first year of a study performed by The Aerospace Corporation to satisfy the Emissions Inventory phase of a federal grant entitled "Analysis of NO_x Control in Stationary Sources." The grant defines a three-year program covering the period 15 July 1974 to 14 July 1977. The purpose of this phase of the program is to assist the Environmental Protection Agency in establishing priorities for detailed studies of techniques for the control of combustion-related emissions from stationary sources. To develop the proper perspective, it was necessary that the inventory include emissions of (1) oxides of nitrogen, (2) unburned hydrocarbons, (3) carbon monoxide, and (4) particulate matter, not only from recognized major stationary combustion sources but also from other stationary source categories in which combustion plays a secondary role. During the first year of this study, emissions were established for 1975 and projected to 1980 from boilers, internal combustion engines, chemical manufacturing, and petroleum refining. In the second year comparative combustion-related emissions data will be obtained for selected industries, including evaporation and primary metals, and the third year will cover mineral products, secondary metals, and wood products. This report identifies approximately 90 percent of all nitrogen oxide emissions and from 30 to 50 percent of unburned hydrocarbons, carbon monoxide, and particulate matter for stationary point sources.

This report is submitted by The Aerospace Corporation under sponsorship of the Environmental Protection Agency in partial fulfillment of Grant Number R803283. The remainder of the grant is fulfilled by the Aerospace report entitled "Analysis of Test Data for NO_x Control in Coal-Fired Utility Boilers," prepared by Owen W. Dykema Aerospace Report No. ATR 76(7549)-2, January 1975 (to be published as an EPA report).

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PART I

SUMMARY OF STUDY AND EMISSION DATA

SECTION ES

EXECUTIVE SUMMARY

ES.1 INTRODUCTION

ES.1.1 Background

A cost-effective approach to nationwide reduction of air pollution requires an accurate assessment of the air pollutants being discharged into the atmosphere by combustion-related processes and other related activity. Since there is a long lead time between the recognition of a large source of air pollution and the implementation of control methods, it is further required that the magnitude of these emissions be estimated for an appropriate time in the future.

Studies of specific industries have been and are being conducted. Because the sources of air pollution are numerous and geographically scattered, few studies have involved the gathering of significant samples of original emission data. Most tend to review, analyse, summarize, and project the same data.

The National Emissions Data System (NEDS) of the U.S. Environmental Protection Agency (EPA) has generated a large volume of detailed, original emission data, covering a wide range of industries. Most of these data were gathered in the 1970 through 1972 time period. Efforts to update the data base are continuing. However, as of 1975, the NEDS data were incomplete, contained some errors, and represented data from an average time period of about 1971. The NEDS contains no system for projecting the data beyond the acquisition period. Despite these drawbacks, the NEDS has the largest, most comprehensive, and detailed sample of original emission data available.

The other studies containing original data surveys serve as a check on the completeness of the NEDS data and provide the rationale for projection of the data into the future.

ES.1.2 Scope

The purpose of this study, which is part of a three-year program, is to assist the EPA in establishing priorities for combustion-related detailed air pollution control studies. The atmospheric pollutants of interest are oxides of nitrogen (NO_x) unburned hydrocarbons (HC), particulate matter (PART), and carbon monoxide (CO). The study utilizes the NEDS original emission data base, as well as original data obtained from individual studies, to generate a detailed inventory of emissions, with projections to the year 1980.

The nationwide emissions inventory compiled by this study is limited to atmospheric point source emissions. Point sources are defined as stationary sources contributing more than 100 tons per year of pollutant. Area sources, i.e., stationary sources of pollution exclusive of point sources, are considered only in cases where a point source is likely to develop.

The industries from which the emissions of interest emanate are referred to as process or source categories and are classified under the NEDS source classification code (SCC). A detailed breakdown of these source categories is further defined by a modified SCC (MSCC) developed by The Aerospace Corporation for this study. The emissions inventoried during the first year of the study, reported here, are from the following major source categories: external combustion in boilers, internal combustion, chemical manufacturing, and petroleum refineries. Evaporation and primary metals emissions will be studied in the second year of the program; emissions from mineral product, secondary metal, and wood product industries will be investigated in the third year.

Uncertainty values are given for the current emission estimates and for emission projections to the year 1980. The variables determining these values are process usage rates, emission factors, control applications, and time derivatives or trends. Statistical engineering estimates, current and potential legislative controls, and several independent sources of data were considered in calculating the uncertainty of each of the emissions inventoried.

ES.1.3 Objectives

The objectives of this study are as follows:

a. Establish current and future five-year estimates of significant nationwide atmospheric stationary point source emissions, particularly from industries involving combustion.

b. Determine the uncertainty of current and future emission rates.

ES.1.4 Approach

The objectives of the study were accomplished by the performance of the following tasks:

a. Establish a list of processes which yield a significant quantity of atmospheric emissions. The selection of processes and subprocesses is described in Sections 1.1.1 and 1.1.2.

b. Determine a data base (starting point) and slopes for time-dependent variables from which current and future emissions can be calculated. Accomplishment of this task for each process is described in Sections 2 through 5.

c. Establish and code equations, for computer usage, which allow emissions and their uncertainties to be estimated for the year of interest. Sections 1.2.1 and 1.2.2 describe these equations.

d. Calculate and publish emissions for the current year and in the year 1980. The detailed results of these calculations are listed for each process in Sections 2 through 5. The summarized results are published in Section 10.

ES.1.5 Organization of This Report

The results of this study are reported in three fundamental areas of this document, grouped into two major parts:

Part I. Summary of Study and Emission Data
Executive Summary
Inventory Summary
Part II. Basic Inventory

The Executive Summary section of Part I presents an overview of the study and a concise review of the significant results, while the Inventory Summary presents the 1975 and 1980 emissions, change rates, and the uncertainties for the three broadest categories of the process studies. In Part II, Basic Inventory, there are two subgroupings: data handling and process studies. The data handling section describes fundamental assumptions and approaches to the development of the entire emissions inventory. This includes descriptions of data acquisition techniques and methods used to perform computational analysis of these data. The process studies are presented in separate sections for each of the four major processes studied in the emissions inventory. Each section is independently oriented. The overall study is a three-year effort scheduled to continue to July 1977. Each year, a selected industry, process, or group of sources will be studied and reported in separate sections of this report. Also, during the third year, the inventory of the previous two years will be updated. The basic report, then, is bound such that subsequent inventories and updates of previous inventories can be easily incorporated.

Metric equivalents for English units used in this report are listed in the conversion table at the back of the document. A glossary of terms is also provided.

ES.2 STUDY SUMMARY

A summary of the stationary point source emissions inventory conducted in the first year of this program is given in Table ES-1 for 1975 and 1980; a summary of all stationary source emissions is shown in Figure ES-1. The general trend of reduced emissions--or, at worst, small increases--between 1975 and 1980, is attributed to increased compliance with new standards during this period even though industrial production is expected to increase appreciably. The most noteworthy emission rate determined is the 1975 CO value from petroleum refineries, which is 17 million

Table ES-1. STATIONARY SOURCE EMISSIONS

Source Category	Emissions, million tons/yr			
	NO_x	HC	CO	PART
Steam Boilers:[a]				
1975	7.59	0.15	0.37	5.58
1980	6.22	0.19	0.44	5.68
Internal Combustion Engines:[a]				
1975	0.60	0.35	Neg[c]	Neg[c]
1980	0.57	0.42	Neg[c]	Neg[c]
Chemical Manufacturing:[a]				
1975	Neg[c]	1.08	2.63	Neg[c]
1980	Neg[c]	1.13	2.76	Neg[c]
Petroleum Refineries:[a]				
1975	0.56	0.41	17.04	0.30
1980	0.38	0.45	11.61	0.24
Internal Combustion Engines:[b]				
1980	2.96	0.99	13.57	Neg

[a] Point source: more than 100 tons per year of pollutant.

[b] Area source: all stationary sources exclusive of point sources.

[c] Neg is defined as less than 1% of the NEDS 1975 stationary source emissions.

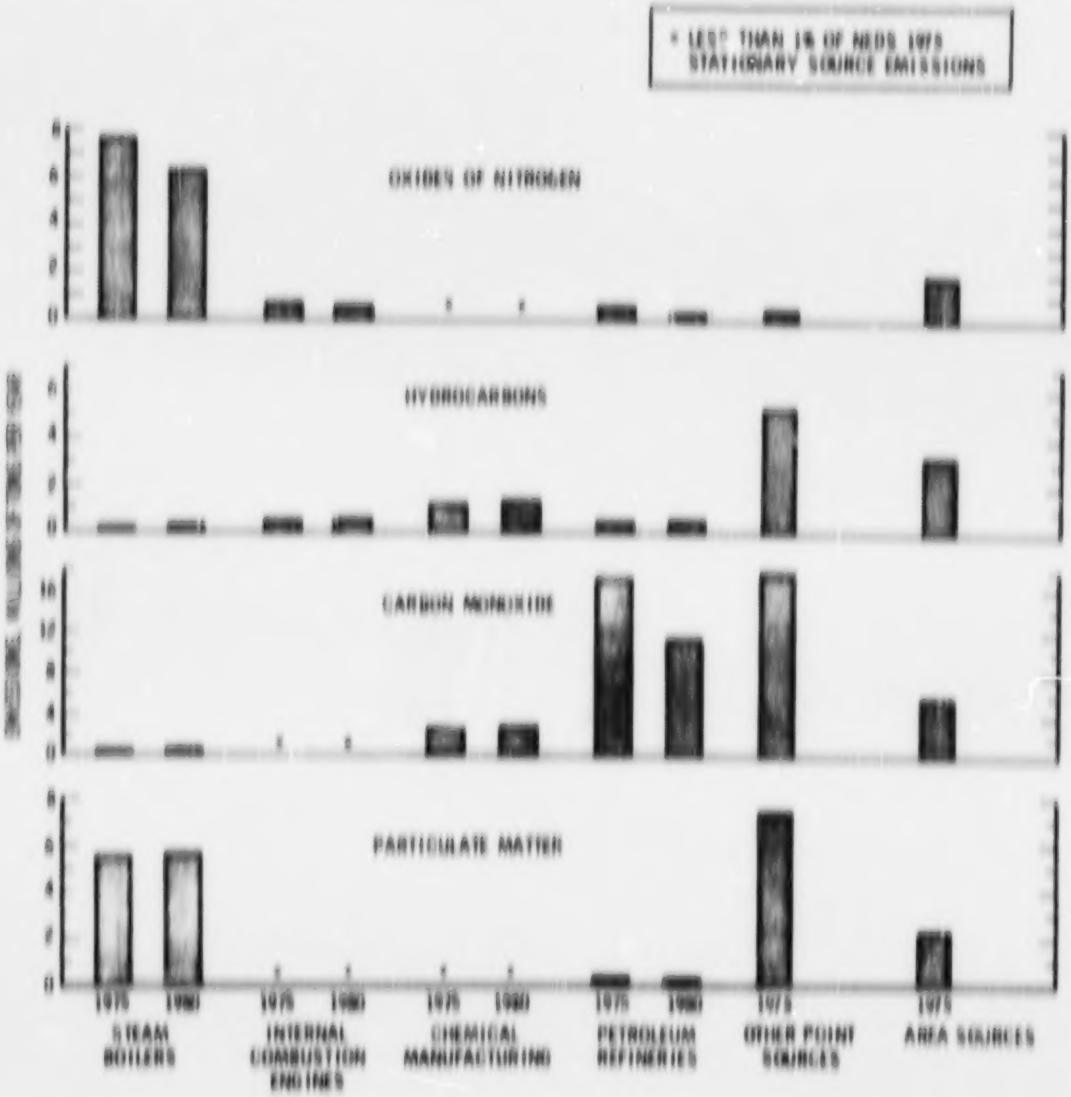

Figure ES-1. Emissions from stationary sources tons per year. This number is approximately four times that reported in any of the recent NEDS nationwide emission summary reports. The difference is attributed partially to a small emission factor used in computing emissions from fluid catalytic cracking processes, but the exact cause for the difference is unresolved at this writing.

As shown in Table ES-2, which identifies the contribution of the inventoried emissions to the total point source emissions, approximately 98 percent of the NO_x and 40 to 50 percent of the HC, CO, and PART are accounted for in this initial inventory. Most of the remainder will be inventoried during the second and third years of this program, which will be concerned with evaporation and primary metal, mineral product, secondary metal, and wood product emissions.

The uncertainties of point source emissions were computed and are presented in Table ES-3. As shown, significant uncertainties in emission rate predictions exist for CO from petroleum refineries. Expressed as a percentage of the nominal value of the predicted emissions, the uncertainty of 1975 CO emissions from refineries is approximately 35 percent. This large uncertainty is due to the lack of substantiated emission factor data for fluid catalytic cracking facilities. Refinements in data are expected to significantly reduce this uncertainty in the updates planned for the third year of the study.

Significant quantities of NO_x, HC, and CO emissions are predicted for stationary area source internal combustion (IC) engines which far exceed the emissions attributed to present point source IC engines.

The difference in emissions is attributed to IC engines whose usage, emission factor, or size is too small to qualify them as point source emitters and consequently are classified as area source emitters. The four highest polluting IC engines contributing to area source emissions were studied because many are in a standby installation and, with a modest increase in

Table ES-2. 1975 DISTRIBUTION OF POINT SOURCE EMISSIONS

Source Category	Percent of Total Point Source Emissions			
	NO_x	HC	CO	PART
Steam Boilers	81	2	1	41
Internal Combustion Engines	6	5	Neg[a]	Neg[a]
Chemical Manufacturing	2	15	7	2
Petroleum Refineries	6	6	45	2
Total Initial Inventory	95	28	53	46
Other Point Sources	5	72	47	54
Total Point Sources	100	100	100	100

[a] Neg is less than 0.5%

Table ES-3. UNCERTAINTIES IN POINT SOURCE EMISSION RATES

Source Category	Emissions, million tons/yr			
	NO_x	HC	CO	PART
Steam Boilers				
1975	+0.42 -0.42	+0.10 -0.02	+0.08 -0.05	+0.47 -0.47
1980	+0.85 -0.81	+0.12 -0.03	+0.10 -0.07	+0.87 -0.87
Internal Combustion Engines				
1975	+0.39 -0.14	+0.18 -0.08	Neg[a]	Neg[a]
1980	+0.42 -0.18	+0.26 -0.11	Neg[a]	Neg[a]
Chemical Manufacturing				
1975	Neg[a]	+0.10 -0.10	+0.37 -0.37	Neg[a]
1980	Neg[a]	+0.11 -0.11	+0.43 -0.43	Neg[a]
Petroleum Refineries				
1975	+0.03 -0.03	+0.04 -0.04	+5.89 -5.89	+0.01 -0.01
1980	+0.03 -0.03	+0.05 -0.05	+6.72 -6.72	+0.02 -0.02

[a] Neg corresponds to the nominal emission equaling less than 1% of total stationary source emissions.

usage, could become point sources of significant quanties of emissions. These four offenders are (1) distillates, (2) crude-oil-fueled turbines (3) diesel engines, and (4) gasoline-fueled reciprocating engines. A detailed description of these area source emissions is presented in Section 3.4. The gasoline engine contributes the largest amount of NO_x, HC, and CO, particularly CO whose rate of 13 million tons per year is two orders of magnitude greater than that of any other area source emission from IC engines. Since the primary objective was to establish an inventory of point source emissions, area source emissions are not included in the basic inventory as summarized in Section III.

SECTION IS

INVENTORY SUMMARY

The categories studied are classified and summarized under the processes contributing the stationary source emissions of interest. In Table IS-1, the major process categories investigated are listed and defined according to the NEDS modified source classification code (MSCC) and charge rate unit. The 1975 and 1980 emissions are similarly summarized by major process category in Tables IS-2-a and IS-3-a, respectively. The respective uncertainties for these emissions are given in Tables IS-2-b and IS-3-b.

In these tables, three levels of summarization are defined by the NEDS nine-digit MSCC number. The first, most general, summary level is indicated by the first digit of the MSCC. The emissions listed in the first-level summary categories in Tables IS-2-a and IS-3-a are the sum of those in the second-level summary, and those in the second level are the sum of those in the third level. Second-level categories are indicated by the second and third digits in the MSCC, and the third-level summary categories by the numbers in the fourth, fifth, and sixth digits.

No charge rates are listed for the first- and second-level summary categories because these categories represent different types of processes with different units of measure. For example, the second-level summary category 101000000 represents all external combustion for boilers used in electric generation including those burning coal in tons per year, oil in thousands of gallons per year, and natural gas in millions of cubic feet per year. In some cases, third-level summaries involve a single process type with the same unit, e.g., 101002000, bituminous coal in tons per year. In such cases, the appropriate MSCC unit of measure is shown in Table IS-1, and a charge rate for this unit is listed in Tables IS-2-a and IS-3-a.

The major source categories summarized here are further classified and detailed in Sections 2 through 5.

Table IS-1. DEFINITION OF SUMMARY CATEGORIES

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[b]	Million cu ft/yr
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr

Table IS-1. DEFINITION OF SUMMARY CATEGORIES (Continued)

MSCC	Source Category	Charge Rate Unit
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr
306000000	Petroleum industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

[b] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table IV-2-a. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES

```
                              EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975       RUN DATE=JUNE 24,1976

  MODIFIED           TACRP                        EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)           NOX              HC               CO            PART

 100000000                           7.591             .147             .371           5.579

 101000000                           6.237             .096             .252           4.301

 101002000         389250000.        4.897             .076             .198           4.205
 101004000          19210000.         .667             .010             .027            .073
 101005000                0.         0.000            0.000            0.000           0.000
 101006000           2993400.         .673             .001             .025            .022
 101007000             90390.         .000         NEGLIGIBLE       NEGLIGIBLE      NEGLIGIBLE

 102000000                           1.354             .057             .119           1.279

 102002000          57234000.         .562             .023             .051           1.065
 102004000          12100000.         .290             .010             .024            .136
 102005000           7060000.         .169             .011             .014            .053
 102006000           3520000.         .303             .005             .030            .032
 102007000           1744300.         .000         NEGLIGIBLE       NEGLIGIBLE      NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table III-2-a. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES (Continued)

INTERNAL COMBUSTION ENGINES PAGE 38

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	NOX	HC	CO	PART
		EMISSIONS (MILLIONS OF TONS / YEAR)			
200000000		.604	.348	.067	.017
201000000		.214	.006	.016	.011
201001000	1088166.	.120	.002	.016	.006
201002000	338060.	.096	.001	.000	.000
201003000	75159.	.011	.061	.005	.002
201999000		.017	.083	.002	.001

MSCC	Source Category	Charge Rate Unit
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table III-2-a. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES (Continued)

INTERNAL COMBUSTION ENGINES PAGE [illegible]

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
202000000		.360	.261	.051	.006
202001000	65953.	.004	.000	.002	.001
202002000	973960.	.348	.084	.044	.004
202003000	3470.	.000	.000	.003	.000
202004000	26201.	.005	.006	.002	.000
202999000	23828.	.003	.172	.061	.000

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table 15-2-a. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES (Continued)

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                  INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING               PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975       RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                     EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC             CO             PART

301000000                         NEGLIGIBLE        1.080          2.625         NEGLIGIBLE

301002000           6100000.      NEGLIGIBLE         .209           .003         NEGLIGIBLE
301003000           2443000.      NEGLIGIBLE         .031           .046         NEGLIGIBLE
301005000           6654400.      NEGLIGIBLE         .322          2.241         NEGLIGIBLE
301999000         151180000.      NEGLIGIBLE         .518           .336         NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table IV-2-a. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, PETROLEUM INDUSTRY - PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
306000000		.557	.407	17.044	.302
306001000		.507	.045	.036	.095
306002000	1500000.	.050	.170	16.800	.180
306003000	108500.	NEGLIGIBLE	.005	.208	NEGLIGIBLE
306008000	26250000.	NEGLIGIBLE	.187	NEGLIGIBLE	NEGLIGIBLE
306012000	116300.	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	.027

MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 18-2-b. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY

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                              EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  38

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975              RUN DATE=JUNE 24,1976

MODIFIED        TACRP                      EMISSIONS (MILLIONS OF TONS / YEAR)
  SCC        (SCC UNITS)           NOX              HC              CO            PART

100000000                        + .417          + .299          + .077          + .471
                                 - .418          - .028          - .052          - .471

101000000                        + .306          + .047          + .071          + .431
                                 - .306          - .015          - .048          - .431

101002000    +   11708000.       + .348          + .047          + .069          + .431
             -   11708000.       - .346          - .016          - .046          - .431
101004000    +    2111300.       + .094          + .008          + .012          + .008
             -    2111300.       - .094          - .006          - .008          - .008
101005000    +          0.       + 0.000         + 0.000         + 0.000         + 0.000
             -          0.       - 0.000         - 0.000         - 0.000         - 0.000
101006000    +     590090.       + .139          + .001          + .012          + .004
             -     590090.       - .139          - .001          - .009          - .004
101007000    +      15220.       + .000          NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
             -      15220.       - .000          NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr

Table 15-2-4. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                              EXTERNAL COMBUSTION, BOILER CATEGORY              PAGE  26

TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1975          RUN DATE=JUNE 24,1976

CLASSIFIED       TACAP                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC       (SCC UNITS)          NOX            HC              CO              PART

102000000                       + .158        + .016          + .048          + .190
                                - .160        - .013          - .022          - .190

102002000    +    6432800.      + .075        + .010          + .020          + .190
             -    6431600.      - .075        - .010          - .014          - .190
102004000    +    1146100.      + .093        + .010          + .012          + .013
             -    1146100.      - .093        - .007          - .009          - .013
102005000    +     838110.      + .058        + .006          + .008          + .006
             -     838110.      - .060        - .004          - .008          - .006
102006000    +     982528.      + .084        + .003          + .017          + .008
             -     982528.      - .084        - .002          - .012          - .008
102007000    +     142990.      + .000       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
             -     142990.      - .000       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 15-2-6. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                          INTERNAL COMBUSTION ENGINES              -        PAGE  38

 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975         RUN DATE=JUNE 24,1976

  MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC         (SCC UNITS)          NOX            HC             CO            PART

 200000000                         + .349         + .178         + .038         + .025
                                   - .137         - .047         - .013         - .009

 201000000                         + .376         + .013         + .029         + .024
                                   - .122         - .012         - .010         - .008

 201001000    +     3320600.       + .369         + .005         + .029         + .024
              -     1608100.       - .120         - .002         - .010         - .008
 201002000    +      417670.       + .072         + .002         + .003         + .001
              -      118206.       - .022         - .001         - .000         - .000
 201003000    +       14799.       + .003         + .000         + .002         + .001
              -       14799.       - .002         - .000         - .001         - .001
 201999000                         + .003         + .012         + .000         + .001
                                   - .003         - .012         - .000         - .001
```

MSCC	Source Category	Charge Rate Unit
20000000	Internal Combustion	
20100000	Electric Generation	
20100100	Distillate oil	1000 gal/yr
20100200	Natural gas	Million cu ft/yr
20100300	Diesel	1000 gal/yr
20199900	Miscellaneous fuel	N.A.[a]

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 15-2-6. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

INTERNAL COMBUSTION ENGINES PAGE 36

TACB AND EMISSION UNCERTAINTIES PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACB (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
202000000		+ .112	+ .177	+ .024	+ .009
		- .061	- .045	- .008	- .004
202001000	+ 22224.	+ .001	+ .000	+ .021	+ .000
	- 22224.	- .001	- .000	- .001	- .000
202002000	+ 616740.	+ .111	+ .030	+ .024	+ .003
	- 174400.	- .061	- .016	- .008	- .004
202003000	+ 1172.	+ .000	+ .000	+ .002	+ .000
	- 1172.	- .000	- .000	- .001	- .000
202004000	+ 26055.	+ .005	+ .000	+ .002	+ .000
	- 26055.	- .005	- .000	- .002	- .000
202999000	+ 5925.	+ .061	+ .175	+ .000	+ .000
	- 5925.	- .001	- .043	- .000	- .000

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table 15-2-b. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                    INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING          PAGE  1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975      RUN DATE=JUNE 24,1976

 MODIFIED        TACRP              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)        NOX           HC             CO              PART

301000000                     NEGLIGIBLE   +  .101      +  .365      NEGLIGIBLE
                              NEGLIGIBLE   -  .101      -  .365      NEGLIGIBLE

301002000   +     229116.     NEGLIGIBLE   +  .028      +  .001      NEGLIGIBLE
            -     229116.     NEGLIGIBLE   -  .028      -  .001      NEGLIGIBLE
301003000   +      54487.     NEGLIGIBLE   +  .004      +  .031      NEGLIGIBLE
            -      54487.     NEGLIGIBLE   -  .004      -  .031      NEGLIGIBLE
301005000   +     226546.     NEGLIGIBLE   +  .072      +  .340      NEGLIGIBLE
            -     226546.     NEGLIGIBLE   -  .072      -  .340      NEGLIGIBLE
301999000   +   17464000.     NEGLIGIBLE   +  .065      +  .129      NEGLIGIBLE
            -   17464000.     NEGLIGIBLE   -  .065      -  .129      NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 15-2-b. SUMMARY OF 1975 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                 INDUSTRIAL PROCESS, PETROLEUM INDUSTRY                       PAGE  1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975           RUN DATE=JUNE 24,1976

 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC              CO              PART

                                   +  .026         +  .035        + 5.890         +  .011
 306000000                         -  .026         -  .035        - 5.890         -  .011

 306001000                         +  .025         +  .006        +  .005         +  .005
                                   -  .025         -  .006        -  .005         -  .005
 306002000      +      30000.      +  .003         +  .009        + 5.890         +  .010
                -      30000.      -  .003         -  .009        - 5.890         -  .010
 306003000      +       2169.      NEGLIGIBLE      +  .000        +  .011         NEGLIGIBLE
                -       2169.      NEGLIGIBLE      -  .000        -  .011         NEGLIGIBLE
 306008000      +     234790.      NEGLIGIBLE      +  .034        NEGLIGIBLE      NEGLIGIBLE
                -     234790.      NEGLIGIBLE      -  .034        NEGLIGIBLE      NEGLIGIBLE
 306012000      +       2199.      NEGLIGIBLE      NEGLIGIBLE     NEGLIGIBLE      +  .002
                -       2199.      NEGLIGIBLE      NEGLIGIBLE     NEGLIGIBLE      -  .002
```

MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 15-3-a. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES

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                        EXTERNAL COMBUSTION, BOILER CATEGORY          -        PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980     RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX           HC           CO           PART

100000000                           6.217         .187         .442         5.675

101000000                           5.057         .118         .292         4.123

101002000        459910000.         4.688         .063         .234         4.001
101004000         26840000.          .245         .027         .040          .107
101005000                0.         0.000        0.000        0.000         0.000
101006000          1982900.          .124         .001         .017          .015
101007000            94390.          .000    NEGLIGIBLE   NEGLIGIBLE   NEGLIGIBLE

102000000                           1.106         .077         .151         1.552

102002000         93319000.          .793         .037         .082         1.287
102004000         15350000.          .138         .023         .031          .177
102005000          8964000.          .081         .113         .018          .067
102006000          2326000.          .147         .003         .020          .021
102007000          1749300.          .000    NEGLIGIBLE   NEGLIGIBLE   NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 18-3-a. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES (Continued)

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                              INTERNAL COMBUSTION ENGINES                                    PAGE  28
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980          RUN DATE=JUNE 24,1976
  MODIFIED          TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)           NOX              HC              CO              PART

200000000                              .568             .418            .066            .018

201000000                              .255             .164            .018            .013

201001000           1275600.           .141             .002            .011            .009
201002000            290630.           .083             .000            .008            .000
201003000             82909.           .012             .001            .005            .002
201999000                              .019             .100            .002            .002
```

MSCC	Source Category	Charge Rate Unit
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 15-3-a. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES (Continued)

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                         INTERNAL COMBUSTION ENGINES                         PAGE  30

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980      RUN DATE=JUNE 24,1976

 MODIFIED           TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX                HC               CO              PART

202000000                            .313              .314             .047             .005

202001000           74753.           .005              .000             .002             .001
202002000          824330.           .297              .076             .037             .004
202003000            4627.           .001              .001             .004             .000
202004000           35626.           .066              .006             .003             .000
202999000           32923.           .005              .237             .001             .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table IS-3-a. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	NOX	HC	CO	PART
			EMISSIONS (MILLIONS OF TONS / YEAR)		
301000000		NEGLIGIBLE	1.126	2.761	NEGLIGIBLE
301002000	7083000.	NEGLIGIBLE	.243	.003	NEGLIGIBLE
301003000	2832500.	NEGLIGIBLE	.036	.024	NEGLIGIBLE
301005000	6217000.	NEGLIGIBLE	.328	2.384	NEGLIGIBLE
301999000	15110000.	NEGLIGIBLE	.519	.336	NEGLIGIBLE

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table IB-3-a. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES (Continued)

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                          INDUSTRIAL PROCESS, PETROLEUM INDUSTRY                 PAGE  1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980      RUN DATE=JUNE 24,1976

 MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC              CO              PART

306000000                           .382             .454          11.609            .239

306001000                           .326             .055            .030            .082
306002000          1690000.         .056             .180          11.441            .128
306003000            70000.    NEGLIGIBLE            .003            .138      NEGLIGIBLE
306008000          2485000.    NEGLIGIBLE            .215      NEGLIGIBLE      NEGLIGIBLE
306012000           120000.    NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE            .029
```

MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 15-3-b. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  38

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980        RUN DATE=JUNE 24,1976

 MODIFIED           TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)           NOX              HC               CO             PART

100000000                            + .859          + .121          + .090          + .067
                                     - .808          - .020          - .067          - .066

101000000                            + .790          + .119          + .048          + .012
                                     - .796          - .019          - .039          - .011

101002000       +   30577000.        + .771          + .118          + .084          + .012
                -   30577000.        - .771          - .017          - .037          - .010
101004000       +    4610700.        + .155          + .012          + .019          + .018
                -    4610700.        - .094          - .029          - .013          - .013
101005000       +          0.        + 0.000         + 0.000         + 0.000         + 0.000
                -          0.        - 0.000         - 0.000         - 0.000         - 0.000
101006000       +    2124500.        + .138          + .002          + .015          + .015
                -    1115800.        - .071          - .011          - .004          - .008
101007000       +      15220.        + .002          NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
                -      15220.        - .00C          NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr

Table 13-3-b. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 16

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

[illegible] SCC		TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX		HC		CO		PART	
102000000			+	.303	+	.023	+	.046	+	.304
			-	.216	-	.026	-	.031	-	.304
102002000	+	12611000.	+	.171	+	.017	+	.034	+	.302
	-	12611300.	-	.171	-	.017	-	.026	-	.302
102004000	+	1686600.	+	.148	+	.013	+	.016	+	.019
	-	1686600.	-	.068	-	.009	-	.011	-	.019
102005000	+	2072900.	+	.096	+	.004	+	.011	+	.016
	-	2072400.	-	.041	-	.006	-	.008	-	.016
102006000	+	2648100.	+	.177	+	.014	+	.025	+	.024
	-	1536900.	-	.097	-	.012	-	.013	-	.014
102007000	+	142990.	+	.006	NEGLIGIBLE		NEGLIGIBLE		NEGLIGIBLE	
	-	142990.	-	.006	NEGLIGIBLE		NEGLIGIBLE		NEGLIGIBLE	

NSCC	Source Category	Charge Rate Unit
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table IS-3-6. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY
(Continued)

INTERNAL COMBUSTION ENGINES PAGE 38

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)		NOX		HC		CO		PART
200000000			+	.418	+	.261	+	.040	+	.026
			-	.176	-	.113	-	.017	-	.018
201000000			+	.394	+	.027	+	.031	+	.029
			-	.143	-	.026	-	.011	-	.009
201001000	+	3472000.	+	.387	+	.005	+	.030	+	.025
	-	1275600.	-	.141	-	.002	-	.011	-	.009
201002000	+	419600.	+	.074	+	.002	+	.003	+	.001
	-	109070.	-	.023	-	.000	-	.000	-	.000
201003000	+	18635.	+	.003	+	.000	+	.002	+	.001
	-	18635.	-	.003	-	.000	-	.001	-	.001
201999000			+	.005	+	.026	+	.001	+	.001
			-	.005	-	.026	-	.001	-	.001

MSCC	Source Category	Charge Rate Unit
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 10-3-6. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                         INTERNAL COMBUSTION ENGINES                              PAGE  26
  TACB AND EMISSION UNCERTAINTIES PROJECTED TO 1980          RUN DATE=JUNE 24,1978
  NATIONAL          TACBP              EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX             HC              CO             PART

  202000000                        + .139         + .266         + .026         + .009
                                   - .102         - .110         - .013         - .003

  202001000    +        49437.     + .063         + .000         + .001         + .001
               -        49437.     - .063         - .000         - .001         - .001
  202002000    +       662170.     + .136         + .037         + .026         + .009
               -       276270.     - .102         - .026         - .013         - .003
  202003000    +         2311.     + .002         + .001         + .003         + .006
               -         2311.     - .026         - .020         - .002         - .000
  202004000    +        26452.     + .005         + .020         + .002         + .000
               -        26452.     - .005         - .004         - .002         - .000
  202999000    +        14045.     + .002         + .258         + .001         + .000
               -        14045.     - .002         - .107         - .001         - .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

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[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table IS-3-b. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY
(Continued)

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX		HC		CO	PART
301000000			NEGLIGIBLE	+	.113	+	.432	NEGLIGIBLE
			NEGLIGIBLE	-	.113	-	.432	NEGLIGIBLE
301002000	+	280470.	NEGLIGIBLE	+	.032	+	.001	NEGLIGIBLE
	-	280470.	NEGLIGIBLE	-	.032	-	.001	NEGLIGIBLE
301003000	+	60686.	NEGLIGIBLE	+	.005	+	.036	NEGLIGIBLE
	-	60686.	NEGLIGIBLE	-	.005	-	.036	NEGLIGIBLE
301005000	+	237320.	NEGLIGIBLE	+	.087	+	.411	NEGLIGIBLE
	-	237320.	NEGLIGIBLE	-	.087	-	.411	NEGLIGIBLE
301999000	+	17464000.	NEGLIGIBLE	+	.065	+	.129	NEGLIGIBLE
	-	17464000.	NEGLIGIBLE	-	.065	-	.129	NEGLIGIBLE

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 15-3-6. SUMMARY OF 1980 EMISSIONS AND CHARGE RATES UNCERTAINTY
(Continued)

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                    INDUSTRIAL PROCESS, PETROLEUM INDUSTRY                 PAGE  1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980          RUN DATE=JUNE 24,1976

 MODIFIED          TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC              CO            PART

306000000                        +   .033       +   .046       + 6.723       +   .016
                                 -   .033       -   .046       - 6.723       -   .016

306001000                        +   .032       +   .056       +   .008      +   .006
                                 -   .032       -   .007       -   .008      -   .006
306002000      +      162480.    +   .006       +   .020       + 6.723       +   .014
               -      162780.    -   .006       -   .020       - 6.723       -   .014
306003000      +       23262.     NEGLIGIBLE    +   .061       +   .048       NEGLIGIBLE
               -       23662.     NEGLIGIBLE    -   .001       -   .048       NEGLIGIBLE
306008000      +     1375200.     NEGLIGIBLE    +   .041        NEGLIGIBLE    NEGLIGIBLE
               -     1375200.     NEGLIGIBLE    -   .041        NEGLIGIBLE    NEGLIGIBLE
306012000      +       11998.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE   +   .024
               -       11944.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE   -   .014
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MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

PART II

BASIC INVENTORY

SECTION 1

DATA HANDLING

1.1 DATA ACQUISITION

1.1.1 Data Selected for Study

It was determined at the outset, by the EPA Project Office, that this study would be restricted to stationary sources of emissions and that the emissions of interest were oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PART). It was also agreed that only point sources (as opposed to area sources) of emissions would be studied. A point source, as defined by the National Emissions Data System (NEDS), is a single stack or geographical point from which more than 100 tons of a given identified air pollutant are discharged annually into the atmosphere. The NEDS is described in detail in Ref. 1-1. The processes which contribute to the atmospheric emissions studied and reported here are described in Refs. 1-2 and 1-3.

The categories of emission sources initially selected for study were determined from the NEDS nationwide emissions report (Ref. 1-4). The order of priority was based largely on the desire to study as many stationary sources of the four emissions in as little time as possible. Table 1-1 shows the emissions from the categories selected for study. The values are as reported in the NEDS Nationwide Emissions Summary, January 10, 1975 (Ref. 1-4).

Table 1-1. STUDY LIST OF EMISSIONS[a]

Source Category	Percent of Total Stationary Source Emissions			
	NO_x	HC	CO	PART
Utility Boilers	48,4	0,8	0,8	23,1
Industrial Boilers	9,6	0,9	1,0	9,8
Process Gas Combustion	0,9	-	-	0,1
Stationary IC Engines[b]	2,6	0,5	0,1	0,1
Petroleum Industry	22,6	9,7	13,9	6,6
Chemical Manufacturing	1,1	22,3	18,4	1,5
Evaporation	-	30,8	-	0,1
Primary Metals	0,1	1,1	24,3	10,1
Mineral Products	1,4	0,1	0,1	25,4
Secondary Metals	0,1	-	4,1	1,1
Wood Products	0,1	0,2	2,8	2,9
Point Source Emissions Selected for Study	86,9	66,4	65,5	80,8
Remaining Point Source Emissions	-	3,6	18,0	4,7
Total Area Source Emissions	13,1	30,0	16,5	14,5
Total Stationary Source Emissions	100,0	100,0	100,0	100,0

[a] Data extracted from Ref. 1-4.

[b] Internal combustion (IC) engines.

Table 1-1 shows that stationary area sources represent from 13 to 30 percent of the emissions of interest. The categories studied in the first year, under study in the second year, and planned for the third year represent from 78 to 100 percent of the four point source emissions identified in Ref. 1-4.

Of the categories inventoried in the first year of this study, utility and industrial boilers and process gas combustion were studied together and are reported in Section 2 under the more general category "external combustion (boiler)." The process gas combustion category was included in this study because an earlier NEDS nationwide emissions summary (emissions as of December 19, 1973) indicated that nearly 20 percent of all NO_x from stationary sources originated from process gas combustion. This information was supported by the large process gas combustion rates listed in Ref. 1-4. Study of the actual data stored in the NEDS (from a data tape) showed that large errors in the original data for two users of process gases accounted for nearly all of the previously reported nationwide process gas usage rates and, therefore, for nearly all of the reported NO_x emissions in this category. These errors were reported, checked, and confirmed by the NEDS personnel, and greatly reduced NO_x emissions are now as reported in Table 1-1.

The stationary internal combustion engines category, although contributing only small quantities of emissions (Ref. 1-4), was chosen because the NO_x emissions could be very large, depending on the usage rates of a large population (Ref. 1-5) of gasoline-fueled engines, each of which is too small to be classed as a point source. Although emissions from point sources in this category are small, the data are summarized, along with a discussion of this critical area source problem, in Section 3.

The chemical manufacturing and petroleum refinery categories were selected because of the high emissions of NO_x, CO, and HC. These categories are reported in Sections 4 and 5, respectively.

Although the categories under study have been referred to as NEDS categories, the NEDS was not the only source, or even in some cases the major source, of original data. Extensive reviews of the literature were also conducted to obtain other original data as well as the rationale for projection of the data into the future. The data obtained, consisting of necessary calculations, sources, and results, are different for each of the general categories studied, and discussions of these data are contained in each of the following sections of this report. The NEDS data acquisition and evaluation techniques were generally common to all categories studied.

1.1.2 Preliminary NEDS Data Evaluation

In each study, a computer tape of all point source data stored in the NEDS for the categories of interest were requested from the NEDS. Initially, the data contained on the tape were analysed (by computer) to determine the significant source classification code (SCC). The NEDS source classification codes are listed and described in Appendix A.2 of Ref. 1-1.) This summary of emissions by the NEDS SCC was reviewed to determine those categories containing the bulk of the four emissions. In most cases it was found that a small number of SCC categories accounted for nearly all of the emissions of each type in the general category chosen for study. Therefore, the total of emissions of some types for the entire general category chosen for study was comparatively insignificant. Considering the rather large ranges of uncertainty in the emissions from other major categories, it was not considered cost-effective to study these small categories. A general measure used to rule out study of certain emissions within a general category or to rule out study of certain SCCs altogether was based on one percent of the total stationary point source emissions. If the sum of any one of the four selected air pollution emissions over the entire general category was less than one percent, emissions of that pollutant were neglected. In certain groups of SCCs, none of the four emissions exceeded one percent, and these SCCs were neglected.

Reference 1-1 lists all the SCCs represented on the NEDS data tape in each of the general categories selected for study. Each data section in this report shows those SCCs studied. The SCCs listed in the appropriate category in Ref. 1-1 but not listed in the corresponding data section of this report were neglected for the above reasons. In cases where any of the four air pollutants were negligible, the data printout indicates "negligible."

The SCCs which were considered significant for one or more of the emissions were then reviewed for data entries indicating excessive process charge rates or emissions. The most commonly used technique to check charge rates was to review the process state of the art, select a large processing plant, and execute a computer search for point sources with listed charge rates greater than this expected maximum. If such cases were discovered, all of the data for that plant and point source were printed for further review. Many cases were found, in this manner, where the listed charge rates were 100 to 1000 times that considered reasonable for a large plant (in some cases even larger than the entire national capacity). In most categories, no equivalent reliable check could be devised, however, for charge rates listed too low. After correction of the data for charge rates listed too high, the corrected total was compared with other original data from the literature.

Erroneously recorded emissions were checked by comparing emission factors calculated from the NEDS tape data on emissions and charge rates against the latest emission factors recorded in Ref. 1-2. Some errors in the listed emissions were uncovered in this manner. A more common error, however, resulted from the accepted practice of calculating the emissions from the best estimate of emission factors and the charge rate, instead of from actual measurements. Since most of the data currently stored in the NEDS was entered in the 1970 through 1972 time period, emission factors were approximately those listed in Ref. 1-3. Corrections in emission factors between the Ref. 1-3 listing and the subsequent listing in Ref. 1-2 in some cases increased or decreased the emission factors by factors of as much as 75 and 40, respectively.

1.1.3 Data Coding

The NEDS data categories are identified by an eight-digit number called the SCC. Where possible and where one or more emissions in a given SCC were large, a further detailed breakdown of the data in that SCC was effected. To facilitate handling of this more detailed data and yet maintain close correspondence with the established NEDS SCC data coding system, a modified SCC (MSCC) system was initiated for this study. A ninth digit was added to all of the eight-digit NEDS SCCs to form the MSCCs used in this study. All of the NEDS SCCs, then, appear in this study with an additional zero in the last place of a nine-digit code number. Where additional breakdown of data in a NEDS SCC was possible and desirable, the last place in the nine-digit code of this study shows a nonzero digit. For example, the NEDS SCC category 10-10-02-02 identifies raw, original data stored for the category: external combustion, boiler (1x-xx-xx-xx); electric generation (10-1x-xx-xx); bituminous coal (10-10-02-xx); fired as pulverized coal in dry-bottom boilers of capacity greater than 100 million Btu/hr (10-10-02-02). This same general category is identified in this study by the MSCC 101002020. This MSCC, in this study, however, is considered a fourth-level summary because the additional breakdowns 101002021 through 101002024 have been included to divide those data into the boiler firing types: tangential, opposed, single-wall, and vertical, respectively. These are now the data levels, and the MSCC 101002020 represents the sum of the emissions and charge rates of the four data SCCs.

Again, although the data coding system used in this study closely parallels that of the NEDS system, the data actually stored and used in this study were acquired from a number of sources (including NEDS). The original data base being accumulated in the data storage and handling program at The Aerospace Corporation, then, represents a careful and judicious sum from other sources as well as NEDS.

1.2 DATA HANDLING AND STORAGE

The sheer volume of data being generated in this study immediately dictates the use of a computer system for storage and handling. After only the first year of study, 102 MSCC categories have been defined for storage of significant data. In each of the MSCCs, 40 separate bits of information must be entered into storage. In any particular MSCC, a particular storage location may contain data either in the form of a number or an indication that the particular data are negligible. Thus, a total of 4080 data entries have already been entered into the program.

The general form of the data storage and handling program is based on two major considerations:

a. The data acquired from various sources represent different points in time. Particularly because of the rapidly changing energy picture, much of those data may have changed considerably between the time of acquisition and the time of this study. Data acquired and stored in general categories at the beginning of this study will be three years older at the time of the first planned update. Users of the data need to have available an estimate of emissions in the time period of implementation of control systems (i.e., in the future) rather than at the time of planning.

b. Complete and accurate original data are difficult to acquire. As a result, little good data are available, and data from several sources are often widely discrepant. As estimates of future emissions are highly desirable, it is important to know how uncertain these projections are.

1.2.1 Data Projections

In response to the need for current and future emissions estimates as well as a set of values upon which these estimates and projections can be evaluated as to their accuracy, a data storage and handling program was developed. As in the NEDS summary system, emissions of each of the four air pollutants NO_x, CO, HC, and PART are calculated from charge rates and emission factors:

Emissions = Emission Factor × Charge Rate (1-1)

For all four of the emissions in a single SCC, the charge rate is the same and is fundamental data in itself. For that reason, storage space is available for three values of the charge rate (with the appropriate year of the data) for each MSCC.

For NO_x, CO, and HC emissions, the appropriate emission factors are entered directly and used with the charge rates as in Eq. (1-1) to calculate emissions. As such, these emission factors directly reflect the average degree of control of emissions in all processes represented by the MSCC. Since the degree of control may change with time, either because of more effective control or more widespread application of the same degree of control, the emission factor must be projected into the future independently of the charge rates.

PART emissions, however, are normally controlled by special hardware. Since these are recognizable pieces of hardware with relatively well-established PART collection efficiencies, both the collector efficiency and the degree of application of such collectors to processes represented in the MSCC can be determined. The emission factors in Eq. (1-1) for PART emissions, then, are calculated from an uncontrolled emission factor for the process, a function of the average collector efficiency, and the average degree of application of this average collector:

PART Emission Factor = Uncontrolled Emission Factor ×
(1 - Collector Efficiency) ×
Fraction of Application of the
Collector (1-2)

It is assumed that the uncontrolled PART emission factor is fundamental to the process and will not change with time. Both the average collector efficiency and the degree of application of this average collector, however, can change with time, and both must be projected independently into the future.

Thus, six time-dependent variables must be entered into the program storage in order to calculate emissions of the four air pollutants of interest: the latest charge rate, the three controlled emission factors, the PART collector efficiency, and the degree of application of the PART collector. Because of the widely varying sources of these data, they hardly ever represent the same period in time. Therefore, the original data cannot be meaningfully combined directly to calculate emissions. The data storage and handling program allows for three separate years of record for (1) the latest charge rate, (2) all three controlled emission factors and the PART control efficiency, and (3) the degree of PART control application. Whenever emissions are calculated, according to Eqs. (1-1) and (1-2), these time-dependent variables must be projected from their individual years of record to the same date.

The projection of these six time-dependent variables into the future required a time-dependent projection equation. In light of the large uncertainties in the original data and the usual uncertainties of the future, no more sophisticated equation than a straight line is justified. Thus, for each of the six time-dependent variables, a linear slope with time (a time derivative) must also be determined from appropriate rationale (e.g., control equation efficiency and degree of application) and stored in the data storage and handling program. All calculations of emissions thus start with the original data for the six time-dependent variables, use the six appropriate linear slopes to project these variables to some common time, and then calculate emissions from the projected values according to Eqs. (1-1) and (1-2). In this report, the charge rate and emission raw data base are generated by projecting all of the data to the current year. A further projection is made for five years into the future.

1.2.2 Data Uncertainties

The second major consideration in the development of the data storage and handling program relates to the uncertainties in the data. As related in Section 1.1.1, data have been found that were in error by two and three orders of magnitude. Differences between independent original sources of the same data are often as large as factors of two. The recent wide variations in charge rates with time, resulting first from the impact of environmental considerations and from the energy shortage, make projections into the future uncertain. If users of the data reported here intend to give weight to certain emissions projected for different sources, then it becomes important that the user have values of the uncertainty in those emissions.

Even an estimate of the uncertainties in the data is difficult because of the lack of data. Adequate data are not available from a sufficient number of original sources that a reasonable statistical estimate of uncertainty can be made. The use of small data sample statistics results in unrealistically large uncertainties. In most cases, only two sources (and sometimes only one source) are available.

Usually, however, certain engineering methods can be followed in estimating realistic bounds on some given data or time-dependent slope from better-known data. For example, current levels of total electrical demand and total installed electric-generating capacity are reasonably widely studied and well documented. By using engineering judgment to set various realistic upper and lower bounds on less well-documented data, such as a breakdown of electric-generating capacity into fuels, firing types, and plant sizes, an engineering estimate of a reasonable uncertainty range around the data on charge rates in large pulverized coal-fired, electric-generating boilers can be obtained. It may also be possible, from a description of a particular study or survey, to make an engineering estimate of the degree of completeness and accuracy of the results. Some cases remain where no data other than a single estimate from the literature and the corresponding NEDS data are available. In such cases, there is no alternative other than to take the data as the average of the two available estimates and the uncertainty range as the difference between the two.

Some fairly clear limits exist, or are defined here, on projections into the future. In most cases, Aerospace familiarity with the basic processes generating or controlling emissions is sufficient that lower limits on emission factors can be estimated with reasonable confidence, at least for the near future. These lower limits are stored in the data storage and handling program, and the program will not allow the NO_x, CO, or HC emission factors (minus the uncertainty) to drop below these limits. Similarly, upper limits are set on PART collector efficiencies. The degree of application of a collector cannot exceed 1.0. Because of the social pressure in all areas to reduce air pollution, the assumption was made in this program that the maximum value of a projected emission factor (the projected nominal value plus the projected uncertainty) cannot exceed the current maximum value (i.e., no increase in emission factors). Of course, no charge rates or emissions, including uncertainties, are allowed to be negative. Limits such as those discussed in this paragraph can result in unsymmetrical uncertainties in projected data levels. For example, the 1975 NO_x emission for MSCC 101002000 is

$$4.897 \begin{array}{l} +1.046 \\ -0.348 \end{array} \times 10^6 \frac{\text{Tons}}{\text{Year}}.$$

The above discussion outlines the methods used and problems encountered in generating engineering estimates of uncertainty in the data shown in this report. The fact that it is so difficult to generate these estimates underlines the need to provide the user with the documentation of the uncertainty of these data. These uncertainties are not statistical quantities. It is necessary, however, to combine the uncertainty estimates of charge rate, emission factor, collector efficiency, control equipment application data, and the derivatives of these with time slopes, to establish the uncertainties of emission data projected into the future. In the data storage and handling program, these are treated as statistical quantities (standard deviation). The resulting uncertainties in the projected emissions are considered engineering estimates.

1.3 REFERENCES

1-1. Guide for Compiling a Comprehensive Emission Inventory, revised, APTD-1135, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (March 1973).

1-2. Compilation of Air Pollutant Emission Factors, 2nd ed., AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

1-3. Compilation of Air Pollutant Emission Factors, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 1972).

1-4. Nationwide Emissions Summary, National Emissions Data System, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (January 10, 1975).

1-5. W. U. Roessler, et al., Assessment of the Applicability of Automotive Emission Control Technology to Stationary Engines, EPA-650/2-74-051, The Aerospace Corporation, El Segundo, California (July 1974).

SECTION 2

EXTERNAL COMBUSTION IN BOILERS

2.1 INTRODUCTION

The external combustion (boiler) category of stationary emission sources includes all of the fuels burned in stationary boilers for the purpose of generating steam for electric generation and various other industrial purposes. According to the National Emissions Data System (NEDS) nationwide emissions report of January 10, 1975 (Ref. 2-1), this category, at least in the 1970 to 1973 time period, represented the largest single stationary source of both oxides of nitrogen (NO_x) and particulate (PART) emissions. NO_x emissions of over 8 million tons per year represented about 59 percent of NO_x emissions from all stationary sources and about 36 percent of NO_x emissions from all sources inventoried by the NEDS. PART emissions of over 5 million tons per year represented about 33 percent of PART emissions from all stationary sources and 31 percent of this air pollutant emitted from all sources. Hydrocarbon (HC) and carbon monoxide (CO) emissions from sources in this category represented less than two percent, each, of those from all stationary sources. The external combustion (boiler) category was the first to be studied in this continuing inventory because of the large NO_x and PART emissions.

A wide range of fuels is burned in external combustion boilers, including the following:

a. Coal: anthracite, bituminous, and lignite
b. Oil: residual and distillate

c. Gas: natural and processed
d. Wood
e. Bagasse
f. Coke
g. Liquified petroleum gas
h. Other minor fuels

Of the NO_x and PART generated from the external combustion of these fuels, for electric generation and various industrial purposes, in single sources emitting more than 100 tons per year of these air pollutants (point sources), the combustion of bituminous coal is by far the largest fuel source. More than 58 and 88 percent of the NO_x and PART, respectively, from the external combustion, boiler category result from the combustion of bituminous coal. Other fuel combustion which contributes significantly to the emission of NO_x and PART includes that of natural gas and oil.

At the time that the fuels to be studied in this portion of the inventory were selected, the then existing NEDS emission summary (Ref. 2-2, dated December 19, 1973) indicated that process gas combustion in industrial boilers and heaters was the source of 2.6 million tons per year of NO_x and resulted from the annual combustion of more than 2×10^{13} cu ft/year of such gaseous fuels. This fuel category, therefore, was included in those to be studied. During the study, it was found that large errors in the fuel usage (annual charge rate) data submitted by two companies accounted for over 90 percent of the listed annual process gas combustion and more than 80 percent of the listed NO_x emissions from process gas combustion. These errors have subsequently been corrected in the NEDS data bank. The NEDS emissions inventory of January 10, 1975 (Ref. 2-1) indicates only about 11,000 tons per year of NO_x from combustion of process gas. Since this fuel category was studied, however, it is included in the projections in this section even though the emissions are small or negligible. No significant effort was made to estimate future changes in process gas usage rates or emission factors.

The fuels selected for study in this inventory were bituminous coal, residual and distillate oil, natural gas, and process gas. These five fuels account for 96 and 92 percent, respectively, of the NO_x and PART generated from external combustion, electric generation, and industrial point sources. All other fuels except lignite and wood represent sources of less than one percent of these pollutants. Lignite represents the source of just over one percent of the pollutants from this category and was neglected. Wood combustion represents the source of nearly two percent and more than four percent of the NO_x and PART, respectively, from this category. The more general category of wood products, including wood combustion, also represents a significant source of CO emissions. As a result, study of the more general categories related to wood use was not neglected but was deferred to a later date.

2.2 SUMMARY

The NEDS source classification code (SCC) for external combustion (boiler) point source categories was modified according to the fuels utilized in utility and industrial boilers and inventoried by this study. Table 2-1, therefore, identifies the source categories studied according to the Aerospace-developed modified source classification code (MSCC) and presents the total annual charge rate projected (TACRP) for each.

A summary of the 1975 and 1980 emissions and TACRP units for the external combustion (boiler) categories was compiled and is given in Tables 2-2-a and 2-3-a, respectively. The uncertainties in the emission and charge rate data for 1975 and 1980 are given in Tables 2-2-b and 2-3-b, respectively.

2.3 APPROACH

Study of fuel usage, emission factors, and projection data in the external combustion (boiler) category was initiated in this study solely from the available literature. In many areas, however, the available data did not provide a sufficient breakdown of firing types nor sufficient multiple sources to evaluate data accuracy (or uncertainty). As a result, a computer

(Continued on page 2-24)

Table 2-1. Definition of External Combustion (Boiler) Processes

MSCC	Source Category	TACRP Unit
101000000	Utility Boilers	
101002000	Bituminous coal	Tons/yr
101002010	>100 MMBtu/hr pulverized wet	Tons/yr
101002020	>100 MMBtu/hr pulverized dry	Tons/yr
101002021	Tangential firing	Tons/yr
101002022	Opposed firing	Tons/yr
101002023	Single-wall firing	Tons/yr
101002024	Vertical firing	Tons/yr
101002030	>100 MMBtu/hr cyclone	Tons/yr
101002040	>100 MMBtu/hr spreader stoker	Tons/yr
101002050	>100 MMBtu/hr overfeed stoker	Tons/yr
101002060	10 to 100 MMBtu/hr pulverized wet	Tons/yr
101002070	10 to 100 MMBtu/hr pulverized dry	Tons/yr
101002080	10 to 100 MMBtu/hr overfeed stoker	Tons/yr
101002090	10 to 100 MMBtu/hr underfeed stoker	Tons/yr
101002100	<10 MMBtu/hr overfeed stoker	Tons/yr
101002110	<10 MMBtu/hr underfeed stoker	Tons/yr
101002120	<10 MMBtu/hr pulverized dry	Tons/yr
101004000	Residual oil	1000 gal/yr
101004010	>100 MMBtu/hr general	1000 gal/yr
101004011	Tangential firing	1000 gal/yr
101004012	Opposed firing	1000 gal/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACBP Unit
101004013	Single-wall firing	1000 gal/yr
101004014	Vertical firing	1000 gal/yr
101004020	10 to 100 MMBtu/hr general[a]	1000 gal/yr
101004030	<10 MMBtu/hr general	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101005010	>100 MMBtu/hr general	1000 gal/yr
101005020	10 to 100 MMBtu/hr general	1000 gal/yr
101005030	<10 MMBtu/hr general	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101006010	>100 MMBtu/hr general	Million cu ft/yr
101006011	Tangential firing	Million cu ft/yr
101006012	Opposed firing	Million cu ft/yr
101006013	Single wall firing	Million cu ft/yr
101006014	Vertical firing	Million cu ft/yr
101006020	10 to 100 MMBtu/hr general	Million cu ft/yr
101006030	<10 MMBtu/hr general	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
101007010	>100 MMBtu/hr general	Million cu ft/yr
101007020	10 to 100 MMBtu/hr general	Million cu ft/yr
101007030	<10 MMBtu/hr general	Million cu ft/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACBP Unit
102000000	Industrial Boilers	
102002000	Bituminous coal	Tons/yr
102002010	>100 MMBtu/hr pulverized wet	Tons/yr
102002020	>100 MMBtu/hr pulverized dry	Tons/yr
102002030	>100 MMBtu/hr cyclone	Tons/yr
102002040	>100 MMBtu/hr spreader stoker	Tons/yr
102002050	10 to 100 MMBtu/hr overfeed stoker	Tons/yr
102002060	10 to 100 MMBtu/hr underfeed stoker	Tons/yr
102002070	10 to 100 MMBtu/hr wet pulverized	Tons/yr
102002080	10 to 100 MMBtu/hr dry pulverized	Tons/yr
102002090	10 to 100 MMBtu/hr spreader stoker	Tons/yr
102002100	<10 MMBtu/hr overfeed stoker	Tons/yr
102002110	<10 MMBtu/hr underfeed stoker	Tons/yr
102002120	<10 MMBtu/hr dry pulverized	Tons/yr
102002130	<10 MMBtu/hr spreader stoker	Tons/yr
102004000	Residual-oil-fired	1000 gal/yr
102004010	>100 MMBtu/hr residual-oil-fired	1000 gal/yr
102004020	1 to 10 MMBtu/hr residual-oil-fired	1000 gal/yr
102004030	<10 MMBtu/hr residual-oil-fired	1000 gal/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACRP Unit
102005000	Distillate-oil-fired	1000 gal/yr
102005010	>100 MMBtu/hr distillate-oil-fired	1000 gal/yr
102005020	10 to 100 MMBtu/hr distillate-oil-fired	1000 gal/yr
102005030	<10 MMBtu/hr distillate-oil-fired	1000 gal/yr
102006000	Natural-gas-fired	Million cu ft/yr
102006010	>100 MMBtu/hr natural-gas-fired	Million cu ft/yr
102006020	10 to 100 MMBtu/hr natural-gas-fired	Million cu ft/yr
102006030	<10 MMBtu/hr natural-gas-fired	Million cu ft/yr
102007000	Process gas-fired	Million cu ft/yr
102007010	>100 MMBtu/hr process gas-fired	Million cu ft/yr
102007020	10 to 100 MMBtu/hr process-gas-fired	Million cu ft/yr
102007030	<10 MMBtu/hr process-gas-fired	Million cu ft/yr

[a] Million British thermal units (MMBtu).

Table 2-2-4. 1975 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
1010020000	304250000.	4.897	.070	.199	4.205
1010020210	45830000.	.573	.007	.023	.826
1010020220	277180000.	2.716	.050	.138	2.942
1010020221	146060000.	.474	.022	.073	1.556
1010020222	58790000.	.781	.005	.029	.624
1010020223	57900000.	.769	.009	.029	.614
1010020224	14360000.	.191	.011	.007	.152
1010020230	54080000.	1.505	.008	.027	.218
1010020240	4200000.	.031	.002	.004	.088
1010020250	4816000.	.013	.001	.002	.026
1010020260	190000.	.002	.000	.000	.007
1010020270	1567200.	.015	.000	.001	.023
1010020280	440000.	.003	.000	.000	.006
1010020290	2350000.	.017	.001	.002	.023
1010022100	38000.	.006	.000	.000	.000
1010022110	0.	0.000	0.000	0.000	0.000
1010022120	1655000.	.016	.000	.001	.055
1010040000	18210000.	.467	.019	.027	.073
1010040410	17960000.	.650	.018	.027	.072
1010040411	7184000.	.166	.007	.011	.029
1010040412	5200000.	.232	.005	.008	.021
1010040413	5200000.	.232	.005	.008	.021
1010040414	376027.	.034	.000	.001	.002
1010040420	240000.	.009	.000	.000	.001
1010040430	10000.	.006	.000	.000	.000
1010050000	0.	0.000	0.000	0.000	0.000
1010050110	0.	0.000	0.000	0.000	0.000
1010050120	0.	0.000	0.000	0.000	0.000
1010050130	0.	0.000	0.000	0.000	0.000

Table 2-2-a. 1975 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
1010060000	2993400.	.673	.001	.025	.022
1010060010	2936000.	.666	.001	.025	.022
1010060011	776000.	.097	.000	.007	.006
1010060012	1209000.	.303	.001	.018	.009
1010060013	964000.	.217	.000	.007	.006
1010060014	88000.	.044	.000	.001	.001
1010060020	53000.	.012	.000	.000	.000
1010060030	4400.	.001	.000	.000	.000
1010070000	90390.	.001	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
1010070010	90390.	.000	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
1010070020	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
1010070030	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
1020020000	57234700.	.592	.023	.051	1.055
1020020010	5940000.	.067	.001	.003	.085
1020020020	5880000.	.058	.001	.003	.123
1020020030	6150000.	.170	.001	.003	.031
1020020040	23120000.	.172	.012	.023	.440
1020020050	1630000.	.098	.001	.001	.025
1020020060	4370000.	.032	.002	.004	.077
1020020070	280000.	.003	.000	.000	.013
1020020080	620000.	.026	.000	.000	.015
1020020090	4794000.	.073	.005	.010	.194
1020020100	276000.	.061	.000	.001	.002
1020020110	120300.	.000	.000	.001	.002
1020020120	0.	0.000	0.000	0.000	0.000
1020020130	340000.	.002	.001	.002	.003
1020040000	12100000.	.291	.016	.024	.139
1020040010	7650000.	.184	.011	.015	.088
1020040020	3420000.	.094	.006	.008	.045

Table 2-2-a. 1975 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 3

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
102004030	530000.	.013	.001	.001	.006
102005000	7060000.	.169	.011	.014	.053
102005010	5186000.	.124	.006	.018	.039
102005020	1684000.	.040	.003	.003	.013
102005030	190000.	.005	.000	.006	.001
102006000	3520000.	.303	.005	.038	.032
102006010	2268000.	.177	.003	.018	.019
102006020	924000.	.575	.001	.008	.008
102006030	536000.	.046	.001	.005	.065
102007000	1744300.	.008	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
102007010	1257000.	.066	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
102007020	464000.	.006	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
102007030	28260.	.206	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Table 2-2-b. 1975 EXTERNAL COMBUSTION UNCERTAINTIES

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                        EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975        RUN DATE=JUNE 24,1976
  MODIFIED           TACRP              EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC           (SCC UNITS)         NOX              HC             CO           PART

 101002000     +   11708000.     +  .348       +  .097       +  .068      +  .431
               -   11708000.     -  .348       -  .014       -  .046      -  .431

 101002010     +    4651900.     +  .098       +  .005       +  .017      +  .271
               -    4651900.     -  .098       -  .004       -  .012      -  .271
 101002020     +    9643300.     +  .253       +  .097       +  .063      +  .325
               -    9643300.     -  .253       -  .013       -  .042      -  .325

 101002021     +    8365000.     +  .166       +  .017       +  .055      +  .282
               -    8365000.     -  .166       -  .011       -  .037      -  .282
 101002022     +    3360300.     +  .134       +  .008       +  .022      +  .113
               -    3360300.     -  .134       -  .004       -  .015      -  .113
 101002023     +    3324500.     +  .132       +  .007       +  .022      +  .112
               -    3324500.     -  .132       -  .004       -  .015      -  .112
 101002024     +     822196.     +  .033       +  .002       +  .005      +  .028
               -     822196.     -  .033       -  .001       -  .004      -  .028

 101002030     +    4686100.     +  .218       +  .006       +  .028      +  .063
               -    4686100.     -  .218       -  .004       -  .014      -  .063
 101002040     +     632460.     +  .006       +  .002       +  .003      +  .027
               -     632460.     -  .006       -  .002       -  .002      -  .027
 101002050     +     172650.     +  .002       +  .001       +  .001      +  .011
               -     172650.     -  .002       -  .001       -  .001      -  .011
 101002060     +      29732.     +  .001       +  .000       +  .000      +  .004
               -      29732.     -  .001       -  .000       -  .000      -  .004
 101002070     +      78142.     +  .003       +  .000       +  .001      +  .003
               -      78142.     -  .003       -  .000       -  .000      -  .003
 101002080     +      63245.     +  .001       +  .000       +  .000      +  .002
               -      63245.     -  .001       -  .000       -  .000      -  .002
 101002090     +     156200.     +  .002       +  .001       +  .002      +  .004
               -     156200.     -  .002       -  .001       -  .001      -  .004
 101002100     +          0.     +  .000       +  .000       +  .000      +  .000
               -          0.     -  .000       -  .000       -  .000      -  .000
 101002110     +          0.     + 0.000       + 0.000       + 0.000      + 0.000
               -          0.     - 0.000       - 0.000       - 0.000      - 0.000
 101002120     +     106300.     +  .003       +  .000       +  .001      +  .042
               -     106300.     -  .003       -  .000       -  .000      -  .042
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Table 2-2-b. 1975 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101004000	+	2111300.	+ .096	+ .009	+ .012	+ .008
	-	2111300.	- .096	- .006	- .008	- .008
102004010	+	2111300.	+ .096	+ .009	+ .012	+ .008
	-	2111300.	- .096	- .006	- .008	- .008
101004011	+	1464000.	+ .041	+ .006	+ .009	+ .006
	-	1464000.	- .041	- .004	- .006	- .006
101004012	+	1080000.	+ .068	+ .004	+ .006	+ .004
	-	1080000.	- .066	- .003	- .004	- .004
101004013	+	1068300.	+ .059	+ .004	+ .006	+ .004
	-	1068300.	- .059	- .003	- .004	- .004
101004014	+	63245.	+ .008	+ .000	+ .000	+ .006
	-	63245.	- .008	- .000	- .000	- .006
101004020	+	0.	+ .001	+ .000	+ .000	+ 0.000
	-	0.	- .001	- .000	- .000	- 0.000
102004030	+	0.	+ .006	+ .000	+ .000	+ 0.000
	-	0.	- .006	- .000	- .000	- 0.000
101005000	+	0.	+ 0.000	+ 0.000	+ 0.000	+ 0.000
	-	0.	- 0.000	- 0.000	- 0.000	- 0.000
101005010	+	0.	+ 0.000	+ 0.000	+ 0.000	+ 0.000
	-	0.	- 0.000	- 0.000	- 0.000	- 0.000
101005020	+	0.	+ 0.000	+ 0.000	+ 0.000	+ 0.000
	-	0.	- 0.000	- 0.000	- 0.000	- 0.000
101005030	+	0.	+ 0.000	+ 0.000	+ 0.000	+ 0.000
	-	0.	- 0.000	- 0.000	- 0.000	- 0.000
101006000	+	590090.	+ .138	+ .001	+ .012	+ .004
	-	590090.	- .138	- .001	- .009	- .004
101006010	+	589870.	+ .138	+ .001	+ .012	+ .004
	-	589870.	- .135	- .001	- .004	- .004
101006011	+	265356.	+ .034	+ .000	+ .005	+ .032
	-	265356.	- .034	- .000	- .004	- .032

Table 2-2-6. 1975 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                        EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  3
TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1975         RUN DATE=JUNE 24,1976
  MODIFIED           TACP                 EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)          NOX              HC               CO            PART

1010006012   +      427930.       +  .109        +  .001         +  .008        +  .003
             -      427930.       -  .109        -  .000         -  .006        -  .003
1010006013   +      305750.       +  .078        +  .000         +  .004        +  .002
             -      305750.       -  .078        -  .000         -  .004        -  .002
1010006014   +       30594.       +  .016        +  .000         +  .001        +  .000
             -       30594.       -  .016        -  .000         -  .000        -  .000

1020006020   +       16000.       +  .004        +  .000         +  .000        +  .000
             -       16000.       -  .004        -  .000         -  .000        -  .000
1010006030   +        1456.       +  .000        +  .000         +  .000        +  .000
             -        1406.       -  .000        -  .000         -  .000        -  .000

1010007010   +       15220.       +  .006      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
             -       15220.       -  .000      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

1020007010   +       15220.       +  .001      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
             -       15220.       -  .000      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
1010007020       NEGLIGIBLE      NEGLIGIBLE    NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
                 NEGLIGIBLE      NEGLIGIBLE    NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
1020007030       NEGLIGIBLE      NEGLIGIBLE    NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
                 NEGLIGIBLE      NEGLIGIBLE    NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

1020012000   +     6431600.       +  .075        +  .016         +  .020        +  .190
             -     6431600.       -  .075        -  .010         -  .014        -  .190

1020022010   +      796490.       +  .014        +  .001         +  .002        +  .020
             -      796490.       -  .014        -  .000         -  .001        -  .020
1020022020   +     4091400.       +  .041        +  .001         +  .003        +  .089
             -     4091400.       -  .041        -  .001         -  .003        -  .089
1020022030   +     1496600.       +  .046        +  .001         +  .002        +  .011
             -     1496600.       -  .046        -  .001         -  .002        -  .011
1020022040   +     4049500.       +  .035        +  .004         +  .018        +  .141
             -     4049500.       -  .035        -  .004         -  .012        -  .141
1020022050   +      106300.       +  .001        +  .000         +  .001        +  .005
             -      106300.       -  .001        -  .000         -  .001        -  .005
1020022060   +      884080.       +  .007        +  .002         +  .003        +  .022
             -      884080.       -  .007        -  .002         -  .002        -  .022
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Table 2-2-b. 1975 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  4

 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975        RUN DATE=JUNE 24,1976

 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX            HC             CD            PART

 102002070    +       34409.     +   .001     +   .000     +   .000     +   .004
              -       34409.     -   .001     -   .000     -   .000     -   .004
 102002080    +      417610.     +   .004     +   .000     +   .000     +   .010
              -      417610.     -   .004     -   .000     -   .000     -   .010
 102002090    +     2099900.     +   .017     +   .004     +   .000     +   .005
              -     2099900.     -   .017     -   .004     -   .005     -   .005
 102002100    +       34409.     +   .000     +   .000     +   .001     +   .001
              -       34409.     -   .000     -   .000     -   .001     -   .001
 102002110    +       12000.     +   .000     +   .000     +   .000     +   .001
              -       12000.     -   .000     -   .000     -   .000     -   .001
 102002120    +           0.     + 0.000      + 0.000      + 0.000      + 0.000
              -           0.     - 0.000      - 0.000      - 0.000      - 0.000
 102002130    +       59464.     +   .001     +   .000     +   .001     +   .002
              -       59464.     -   .001     -   .000     -   .001     -   .002

 102004000    +     1146100.     +   .093     +   .016     +   .012     +   .013
              -     1146100.     -   .093     -   .007     -   .009     -   .013

 102004010    +     1062930.     +   .083     +   .009     +   .011     +   .012
              -     1062930.     -   .083     -   .004     -   .008     -   .012
 102004020    +      405140.     +   .042     +   .005     +   .006     +   .005
              -      405140.     -   .042     -   .003     -   .004     -   .005
 102004030    +       53073.     +   .006     +   .001     +   .001     +   .001
              -       53073.     -   .006     -   .000     -   .001     -   .001

 102005000    +      836110.     +   .066     +   .006     +   .008     +   .006
              -      836110.     -   .066     -   .004     -   .006     -   .006

 102005010    +      807225.     +   .057     +   .006     +   .007     +   .006
              -      807225.     -   .057     -   .004     -   .005     -   .006
 102005020    +      223730.     +   .018     +   .002     +   .002     +   .002
              -      223730.     -   .018     -   .001     -   .002     -   .002
 102005030    +       27724.     +   .002     +   .001     +   .000     +   .000
              -       27724.     -   .002     -   .000     -   .000     -   .000

 102006000    +      902520.     +   .096     +   .003     +   .017     +   .008
              -      902520.     -   .096     -   .002     -   .012     -   .006
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Table 2-2-b. 1975 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                          EXTERNAL COMBUSTION, BOILER CATEGORY                      PAGE  5
             TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975        RUN DATE=JUNE 24,1976
   MODIFIED         TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC         (SCC UNITS)          NOX              HC               CO             PART

 102006010    +     826610.        +  .077        +  .003        +  .015        +  .007
              -     826610.        -  .061        -  .002        -  .011        -  .007
 102006020    +     316540.        +  .036        +  .001        +  .006        +  .003
              -     316540.        -  .032        -  .001        -  .005        -  .003
 102006030    +     180280.        +  .017        +  .001        +  .004        +  .002
              -     180280.        -  .014        -  .000        -  .003        -  .002

 102007011    +     142990.        +  .000      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
              -     142990.        -  .000      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE

 102007010    +     125700.        +  .006      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
              -     125700.        -  .006      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
 102007020    +      68100.        +  .001      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
              -      68100.        -  .000      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
 102007030    +       2800.        +  .000      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
              -       2800.        -  .000      NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE
```

Table 2-3-a. 1980 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101002600	459915000.	4.688	.083	.236	4.061
101002610	45830000.	.458	.007	.023	.666
101002620	339106000.	2.716	.061	.164	2.979
101002621	178210000.	.875	.027	.084	1.576
101002622	71730000.	.781	.011	.036	.632
101002623	70650000.	.749	.011	.035	.622
101002624	17510000.	.141	.013	.009	.154
101002630	63030000.	1.428	.004	.032	.108
101002640	4200000.	.025	.002	.004	.066
101002650	1810000.	.011	.001	.002	.026
101002660	190000.	.002	.000	.000	.005
101002670	1910200.	.015	.000	.001	.024
101002680	[illegible]	.003	.000	.000	.005
101002690	[illegible]	.014	.001	.002	.017
101002700	30000.	.002	.000	.000	.000
101002710	0.	0.000	0.000	0.000	0.000
101002720	2020300.	.018	.000	.001	.037
101004600	26860000.	.245	.027	.048	.107
101004610	26610000.	.243	.027	.048	.106
101004611	10644200.	.059	.011	.016	.043
101004612	7700000.	.085	.008	.012	.031
101004613	7700000.	.085	.008	.012	.031
101004614	566000.	.013	.001	.001	.002
101004620	244000.	.002	.000	.000	.001
101004630	10000.	.000	.000	.000	.000
101005000	0.	0.000	0.000	0.000	0.000
101005010	0.	0.000	0.000	0.000	0.000
101005020	0.	0.000	0.000	0.000	0.000
101005030	0.	0.000	0.000	0.000	0.000

Table 2-3-a. 1980 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101006000	1986400.	.124	.001	.017	.015
101006010	1951600.	.122	.001	.017	.015
101006011	516000.	.018	.000	.004	.004
101006012	863000.	.056	.000	.007	.006
101006013	574000.	.040	.000	.005	.014
101006014	58000.	.009	.000	.000	.000
101006020	330000.	.002	.000	.000	.000
101006030	2900.	.000	.000	.000	.000
101007000	90390.	.006	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
101007010	90290.	.000	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
101007020	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
101007030	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
102002000	49319000.	.743	.237	.082	1.287
102002010	8190000.	.082	.001	.004	.102
102002020	11330000.	.091	.002	.006	.192
102002030	10600000.	.240	.002	.005	.040
102002040	40220000.	.242	.020	.040	.638
102002050	1790000.	.011	.001	.002	.031
102002060	7520000.	.046	.004	.008	.092
102002070	410000.	.004	.000	.000	.014
102002080	1170000.	.009	.000	.001	.022
102002090	16700000.	.065	.003	.011	.148
102002100	470000.	.042	.001	.002	.003
102002110	170000.	.002	.000	.001	.002
102002120	0.	0.000	0.000	0.000	0.000
102002130	590000.	.003	.001	.003	.005
102004000	15350000.	.138	.023	.031	.177
102004010	9700000.	.287	.015	.019	.112
102004020	4970000.	.345	.007	.010	.657

Table 2-3-a. 1980 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980      RUN DATE=JUNE 24,1976
 MODIFIED         TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)         NOX             HC              CO             PART

102004030        686060.          .006            .001            .001            .004

102005000       8960000.          .081            .013            .018            .067

102005010       6596000.          .055            .010            .013            .045
102005020       2134000.          .018            .003            .004            .016
102005030        240000.          .002            .000            .000            .002

102006010       2320000.          .147            .003            .020            .021

102006010       1360000.          .036            .002            .012            .012
102006020        809500.          .038            .001            .005            .005
102006030        351500.          .022            .001            .003            .003

102007000       1749300.          .006        NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

102007010       1257000.          .000        NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
102007020        464000.          .000        NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
102007030         26260.          .002        NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
```

Table 2-3-b. 1980 EXTERNAL COMBUSTION UNCERTAINTIES

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)		NOX		HC		CO		PART
				EMISSIONS (MILLIONS OF TONS / YEAR)						
1010062000	+	30577030.	+	.771	+	.118	+	.084	+	.812
	-	30577030.	-	.771	-	.017	-	.057	-	.818
1010062010	+	14835000.	+	.218	+	.006	+	.019	+	.321
	-	14835000.	-	.218	-	.004	-	.014	-	.321
1010062020	+	23282000.	+	.486	+	.118	+	.078	+	.739
	-	23282000.	-	.486	-	.016	-	.053	-	.737
1010062021	+	28194000.	+	.321	+	.021	+	.060	+	.641
	-	28194000.	-	.321	-	.014	-	.046	-	.646
1010062022	+	8108100.	+	.258	+	.002	+	.027	+	.258
	-	8108100.	-	.258	-	.006	-	.018	-	.257
1010062023	+	8032200.	+	.253	+	.001	+	.027	+	.254
	-	8032200.	-	.253	-	.005	-	.018	-	.254
1010062024	+	1989100.	+	.063	+	.010	+	.007	+	.063
	-	1989100.	-	.063	-	.001	-	.004	-	.063
1010062030	+	12952000.	+	.556	+	.008	+	.025	+	.078
	-	12952000.	-	.556	-	.005	-	.017	-	.078
1010062040	+	2109500.	+	.015	+	.002	+	.004	+	.042
	-	2109500.	-	.015	-	.002	-	.003	-	.042
1010062050	+	506100.	+	.005	+	.001	+	.001	+	.011
	-	506100.	-	.005	-	.001	-	.001	-	.011
1010062060	+	98508.	+	.001	+	.000	+	.000	+	.004
	-	98508.	-	.001	-	.000	-	.000	-	.004
1010062070	+	215876.	+	.005	+	.000	+	.001	+	.006
	-	215876.	-	.005	-	.000	-	.000	-	.006
1010062080	+	210950.	+	.002	+	.000	+	.000	+	.003
	-	210950.	-	.002	-	.000	-	.000	-	.003
1010062090	+	431740.	+	.005	+	.001	+	.002	+	.008
	-	431740.	-	.005	-	.001	-	.001	-	.010
1010062100	+	0.	+	.000	+	.000	+	.000	+	.000
	-	0.	-	.000	-	.000	-	.000	-	.000
1010062110	+	0.	+	0.000	+	0.000	+	0.000	+	0.000
	-	0.	-	0.000	-	0.000	-	0.000	-	0.000
1010062120	+	-288620.	+	.006	+	.000	+	.001	+	.035
	-	288620.	-	.006	-	.000	-	.001	-	.037

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Table 2-3-h. 1980 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)		NOX		HC		CO		PART
				EMISSIONS (MILLIONS OF TONS / YEAR)						
101004006	+	4618766.	+	.155	+	.012	+	.019	+	.018
	-	4618766.	-	.094	-	.009	-	.013	-	.018
101004010	+	4618766.	+	.155	+	.012	+	.019	+	.018
	-	4618766.	-	.094	-	.009	-	.013	-	.018
101004011	+	3175500.	+	.068	+	.009	+	.013	+	.013
	-	3175500.	-	.027	-	.006	-	.009	-	.013
101004012	+	2463000.	+	.098	+	.006	+	.018	+	.010
	-	2463000.	-	.063	-	.003	-	.007	-	.010
101004013	+	2337400.	+	.040	+	.006	+	.018	+	.009
	-	2337900.	-	.063	-	.005	-	.007	-	.006
101004014	+	92195.	+	.014	+	.000	+	.001	+	.000
	-	92195.	-	.011	-	.000	-	.000	-	.000
101004020	+	0.	+	.002	+	.010	+	.000	+	0.000
	-	0.	-	.001	-	.005	-	.000	-	0.000
101004030	+	0.	+	.000	+	.000	+	.000	+	0.000
	-	0.	-	.000	-	.000	-	.000	-	0.000
101005006	+	0.	+	0.000	+	0.000	+	0.000	+	0.000
	-	0.	-	0.000	-	0.000	-	0.000	-	0.000
101005010	+	0.	+	0.000	+	0.000	+	0.000	+	0.000
	-	0.	-	0.000	-	0.000	-	0.000	-	0.000
101005020	+	0.	+	0.000	+	0.000	+	0.000	+	0.000
	-	0.	-	0.000	-	0.000	-	0.000	-	0.000
101005030	+	0.	+	0.000	+	0.000	+	0.000	+	0.000
	-	0.	-	0.000	-	0.000	-	0.000	-	0.000
101006002	+	2029500.	+	.136	+	.001	+	.019	+	.015
	-	1115900.	-	.071	-	.001	-	.009	-	.008
101006010	+	2028700.	+	.136	+	.001	+	.019	+	.015
	-	1115300.	-	.071	-	.001	-	.009	-	.008
101006011	+	911540.	+	.033	+	.000	+	.008	+	.007
	-	516400.	-	.018	-	.000	-	.004	-	.004

Table 2-3-b. 1980 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                           EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  3
TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1980        RUN DATE=JUNE 24,1976
 MODIFIED          TACHP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC              CO              PART

101006012   +     1472300.       +   .106        +   .001       +   .014       +   .011
            -      803000.       -   .056        -   .000       -   .007       -   .006
101006013   +     1651700.       +   .076        +   .001       +   .018       +   .008
            -      574000.       -   .046        -   .000       -   .005       -   .004
101006014   +      125170.       +   .015        +   .001       +   .001       +   .001
            -       58000.       -   .008        -   .000       -   .000       -   .000

101006020   +       56000.       +   .004        +   .000       +   .001       +   .000
            -       33000.       -   .002        -   .000       -   .000       -   .000
101006030   +        4960.       +   .000        +   .000       +   .000       +   .000
            -        2900.       -   .000        -   .000       -   .000       -   .000

101007010   +       15220.       +   .001       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
            -       15220.       -   .000       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

101007015   +       15220.       +   .001       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
            -       15220.       -   .000       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
101007020      NEGLIGIBLE        NEGLIGIBLE     NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
               NEGLIGIBLE        NEGLIGIBLE     NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
101007030      NEGLIGIBLE        NEGLIGIBLE     NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
               NEGLIGIBLE        NEGLIGIBLE     NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

102002000   +    12611000.       +   .171        +   .017       +   .034       +   .302
            -    12611000.       -   .171        -   .017       -   .024       -   .302

102002010   +     2226900.       +   .036        +   .001       +   .003       +   .036
            -     2226900.       -   .036        -   .001       -   .002       -   .036
102002020   +     5006000.       +   .049        +   .002       +   .005       +   .104
            -     5006000.       -   .049        -   .001       -   .004       -   .104
102002030   +     3977800.       +   .120        +   .001       +   .004       +   .021
            -     3977800.       -   .120        -   .001       -   .003       -   .021
102002040   +     9981500.       +   .106        +   .016       +   .032       +   .266
            -     9981500.       -   .106        -   .016       -   .022       -   .266
102002050   +      288620.       +   .004        +   .001       +   .001       +   .011
            -      288620.       -   .004        -   .001       -   .001       -   .012
102002060   +     2015500.       +   .019        +   .003       +   .006       +   .041
            -     2015500.       -   .019        -   .003       -   .004       -   .043
```

Table 2-3-b. 1980 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

```
                    EXTERNAL COMBUSTION, BOILER CATEGORY                      PAGE  4
 TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1986          RUN DATE=JUNE 24,1976
 MODIFIED          TACRP               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX             HC              CO              PART

 102002070   +      100020.    +   .002    +   .000    +   .000    +   .007
             -      100020.    -   .002    -   .000    -   .000    -   .007
 102002080   +      500000.    +   .005    +   .001    +   .001    +   .012
             -      500000.    -   .005    -   .000    -   .000    -   .012
 102002090   +     3002900.    +   .028    +   .004    +   .009    +   .092
             -     3002900.    -   .029    -   .004    -   .006    -   .093
 102002100   +      100020.    +   .001    +   .000    +   .001    +   .002
             -      100020.    -   .001    -   .000    -   .001    -   .002
 102002110   +       42000.    +   .000    +   .000    +   .000    +   .001
             -       42000.    -   .006    -   .000    -   .000    -   .001
 102002120   +           0.    + 0.000     + 0.000     + 0.000     + 0.000
             -           0.    - 0.000     - 0.000     - 0.000     - 0.000
 102002130   +      197823.    +   .003    +   .001    +   .002    +   .004
             -      197526.    -   .002    -   .001    -   .002    -   .003

 102004000   +     1686500.    +   .148    +   .013    +   .016    +   .029
             -     1686500.    -   .066    -   .005    -   .011    -   .019

 102004010   +     1609600.    +   .132    +   .011    +   .034    +   .018
             -     1609600.    -   .054    -   .008    -   .018    -   .018
 102004020   +      500600.    +   .057    +   .006    +   .007    +   .006
             -      500600.    -   .027    -   .004    -   .005    -   .006
 102004030   +       79862.    +   .009    +   .001    +   .001    +   .001
             -       79862.    -   .004    -   .001    -   .001    -   .001

 102005090   +     2072900.    +   .096    +   .009    +   .011    +   .018
             -     2072900.    -   .041    -   .006    -   .008    -   .016

 102005010   +     1983000.    +   .091    +   .008    +   .018    +   .015
             -     1983000.    -   .034    -   .006    -   .008    -   .015
 102005020   +      600050.    +   .029    +   .013    +   .003    +   .005
             -      600050.    -   .013    -   .002    -   .002    -   .005
 102005030   +       70113.    +   .003    +   .000    +   .000    +   .001
             -       70113.    -   .001    -   .000    -   .000    -   .001

 102006020   +     2648100.    +   .177    +   .004    +   .025    +   .024
             -     1530900.    -   .097    -   .002    -   .013    -   .014
```

Table 7-3-b. 1980 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                        EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  5

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980          RUN DATE=JUNE 24,1976

  MODIFIED           TACRP                        EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)              NOX                HC                 CO                 PART

1020060110    +     2363500.       +   .158        +   .004        +   .022        +   .021
              -     1360000.       -   .086        -   .002        -   .012        -   .012
1020060120    +     1033000.       +   .069        +   .002        +   .018        +   .009
              -      609000.       -   .036        -   .001        -   .005        -   .005
1020060130    +      598020.       +   .046        +   .001        +   .006        +   .005
              -      352000.       -   .022        -   .001        -   .003        -   .003

1020070100    +      142996.       +   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
              -      142996.       -   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE

1020070110    +      125700.       +   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
              -      125700.       -   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
1020070120    +       68100.       +   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
              -       68100.       -   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
1020070130    +        2800.       +   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
              -        2800.       -   .000        NEGLIGIBLE         NEGLIGIBLE         NEGLIGIBLE
```

tape was obtained from the NEDS data bank containing card images of all stored point source data for utility and industrial boilers, SCC 1-01-001-01 through 1-02-999-99 (see Ref. 2-3 for definition of terms and SCC categories). It was necessary to write computer programs to extract, summarize, and check the data contained on this tape. Much of the literature search and literature data analyses were completed by the time the NEDS tape data became one in which complete data acquisition and projection was first accomplished from existing sources in the published (and some unpublished) literature. The NEDS tape data was used as a second data source, both to accomplish a further breakdown of some of the larger source categories into more detailed firing types and to provide a means of estimating the accuracy, or uncertainty, of the data.

In the special case of process gas combustion, the situation was reversed in that little or no data existed in the literature but the NEDS data indicated large fuel usage rates and NO_x emissions. In that case, only the NEDS tape data were examined in detail, and uncertainties were derived from that data analysis alone. As discussed in Section 2.1, the errors found were sufficiently large to reduce that category to negligible proportions.

The SCC external combustion (boilers) category was subdivided according to the fuels selected for study within this category, which are represented by 58 MSCC categories. In order to accomplish the type of linear projections into the future, with cited uncertainties, as described in Section 1, a total of 39 distinct input numbers had to be generated for each MSCC. Thus, for this category alone, a total of 2,262 separate data entries had to be considered.

In general, initial efforts were made, from data in the literature, to estimate current values of fuel usage rates and emission factors. The NEDS data were used to improve and confirm these estimates, provide further breakdowns into finer categories, and estimate uncertainties in current data levels. Methods of projecting data into the future could only be derived from the literature and other unpublished data sources. All data sources were also used to estimate uncertainties in the projection methods and the resulting levels projected to 1980. The resulting data level estimates and uncertainties were then used to derive the linear slopes and the uncertainties in these slopes.

Since the literature search and analyses of data from the literature provided a major source of current data and the only source of projection data and methods, these data and analyses are discussed in depth in Section 2.3. In most cases, the data finally used in the projections were reviewed and somewhat modified (or established) by subsequent comparison with NEDS tape derived data. A discussion of the NEDS data is contained in Section 2.4.

2.4 DATA ANALYSIS FROM LITERATURE

Data in the literature can be divided into the source categories of utility boilers and industrial boilers. Data concerning these two sources are sufficiently different, both in depth and type, that separate data sources and analyses were necessary to derive the desired data. Further, PART control equipment efficiency and degree of application data represented a special effort. Therefore, studies in these three areas were generally conducted separately.

2.4.1 Fuel Usage, NO_x, HC, and CO Emissions in and from Utility Boilers

An Edison Electric Institute (EEI) survey (Ref. 2-4) of several hundred utility steam generator units provided data on boiler firing type, fuel type, and unit megawatt electrical design capacity. This survey provided the basis for a proportional breakdown of burner firing types categorized as follows: tangential, opposed wall, front or back wall, cyclone, and vertical. The sample contained in the EEI survey was sufficiently large to be deemed representative of the overall utility industry.

Since many utility stations were shown to have multifuel operating capability, a further time-related refinement was required. Annual fuel usage statistics for multifuel-fired plants were sampled (Ref. 2-5). The sample size chosen for analysis of these data was arbitrarily limited to utilities with power capability exceeding ~400 MW. This was done for reasons of manageability. The average proportions of annual usage of each fuel as reported for these stations (coal/oil, oil/gas, coal/oil/gas) were acquired. In the analysis, data were weighted to account for differences in fuel heating values. The proportional statistics for adjusted fuel consumption and breakdown by firing type were then used to develop a summary breakdown expressed as the percent of total energy output.

The total estimated 1973 electrical energy output of the United States was 1.88×10^{12} kW-hr (Ref. 2-6). The fossil-fueled steam electric energy value of 1.43×10^{12} kW-hr is about 76 percent of the total annual output (Refs. 2-7 and 2-8). An average plant net heating rate of 10,350 Btu/kW-hr was selected as representative of the industry (Refs. 2-9 and 2-10). This equals an electrical conversion efficiency of 33 percent, a figure which is somewhat below the most efficient of recently installed large units but which conservatively accounts for many of the older units still in operation.

With these factors, tables were derived for electrical and heat energy generation by firing type. The heating values for coal, oil, and gas, taken as 25×10^6 Btu/ton, 142,800 Btu/gal, and 1050 Btu/cu ft, respectively, enabled the determination of fuel consumption by firing type.

Emission factors published by the Environmental Protection Agency (EPA) (Ref. 2-11) are given in pounds of pollutants per unit fuel usage and are categorized by source. Additional data on tangential-fired furnace emissions were obtained from other sources. (Refs. 2-12 and 2-13). The product of fuel usage multiplied by the appropriate emission factor (CO, HC, NO_x) provided the detailed data breakdown for the stationary power plant emission inventory by boiler firing type.

Projections of emissions for 1980 involved establishment of expected fuel usage figures for that year (Ref. 2-8). However, current drastic changes in socioeconomic conditions may strongly affect actual overall electric energy demand in 1980 as well as the fuel mix used to supply that demand. The differences between current fuel usage and the 1980 usage estimates represent new construction.

Boiler construction figures by firing type were not readily obtainable in the short time span of the study. Speculative consideration was given to recent trends showing that Combustion Engineering, supplier of tangential furnaces, has shown increasing market penetration and is currently reported (Ref. 2-14) to be controlling about 43 percent of the new boiler market. In addition, multifuel firing capability, already in common practice, tends to favor a shift in this direction with coal remaining as the predominant fuel, especially in view of uncertainties in the future availability of oil and gas. Thus, the 1980 fuel usage breakdown, reflecting these considerations, is based on the assumption that one half of the new construction for fuel consumption (coal, oil, and gas) will be allocated to tangential-fired units, and the remaining one half will be proportioned as in 1973. The incremental fuel usage values were summed to the 1973 usages to obtain 1980 projections.

The new construction is expected to fulfill the EPA national emissions requirements already legislated (Ref. 2-15). It is further anticipated that improvements in existing units will be forthcoming. Exploratory efforts concerning the feasibility of reduced NO_x by means of combustion modifications have shown promise in several investigations (Refs. 2-12, 2-16, and 2-17). Therefore, slightly lower emission factors were assumed for NO_x emitted from existing facilities.

For all coal-fired furnaces, it was assumed that the 1980 NO_x emission factors could be reduced by 25 percent from the 1973 factors listed in Ref. 9. NO_x emission factors estimated for coal in 1980, were 13.5 lb/ton for all pulverized firing and 41 lb/ton for cyclone furnaces. The 1973 NO_x emission factors for gas and oil, converted to parts per million (PPM) in the flue gas, are 273 for oil and 238 for gas in tangential-fired boilers and 572 for oil and 476 for gas in other firing types. Recent efforts to reduce NO_x emissions in utility boilers indicate that simple, practical combustion modifications can reduce NO_x emissions in both gas- and oil-fired utility boilers at least to 200 parts per million. On the assumption that this technology is currently available and will be widely implemented by 1980, NO_x emission factors of 36 $lb/10^3$ gal of oil and 250 $lb/10^6$ cu ft of gas in all firing types were estimated.

Although there is little well-documented information in the technical literature, the popular media and personal observation of some public and private utilities indicate that natural gas may disappear as a fuel for electric generation well before 1980. Many utilities are already experiencing long seasonal periods during which natural gas fuels are not available. Even the highly publicized Alaskan natural gas supply, when fully developed, is expected to deliver less than 10 percent of the current demand in utility and industrial boilers alone. For these reasons, projected natural gas usage in utility and industrial boilers was estimated to decrease at a slope (and slope uncertainty) which indicates zero usage as early as 1978. Considering the unsubstantiated quality of this type of popular data, however, the uncertainty in this negative slope is large. The projected electrical demand which would have been supplied by natural gas combustion was shifted to coal-burning utilities and coal- and oil-burning industrial boilers.

In general, HC and CO emissions from external combustion boilers are low and usually well below the limits of any foreseen regulations. For this reason, no effort was made to project changes in HC and CO emission factors. In all cases in this category, HC and CO slopes were considered equal to zero.

2.4.2 Fuel Usage, NO_x, HC, and CO Emissions in and from Industrial Boilers

The three major pieces of information needed to calculate the industrial boiler emissions are the installed boiler capacity, the consumption of each type of fuel, and the emission factors. Within the time constraints of this study, only a limited literature search and a survey of potential information sources were possible. For boiler capacity data, the only source located was Ref. 2-18, in which were several tables based on information in Ref. 2-19 (the latter report, by Ehrenfeld, could not be obtained by the Aerospace library). In those tables, industrial boiler capacities were given for 1967, with projections to 1975 and 1980, in terms of total steam generation in pounds per hour. An estimate was made of the breakdown of the 1967 total capacity into three size categories: 10 to 100, 100 to 250, and

250 to 500 KPPH.[7] Sales data from Ref. 2-20 were used to project how the total capacity would be divided into these three size ranges in 1973 and 1980.

The Ehrenfeld 1967 data given in Ref. 2-18 also included coal, oil, and natural gas annual consumption for the industrial boilers. Using heating values for the coal (25×10^6 Btu/ton), oil (6×10^6 Btu/bbl), and gas (1050 Btu/cu ft) and assuming 1000 Btu/lb heat content of steam, it was possible to relate capacity data in heat output per hour to the annual heat input. A factor of 3800 was derived, an average factor, in hours per year at rated capacity operation. Lacking any later data along these lines, this factor was used for all subsequent year calculations to relate boiler capacities to heat input and thus to total annual fuel consumption.

Next, the total fuel consumption derived for 1973 and 1980 was divided among coal, oil, and gas. The boiler population data in Ref. 2-20 (for 1972) were used to estimate the 1973 fuel usage split. Although these data are boiler number percentages rather than capacity percentages, there are sufficient size categories that the two percentages should not be widely different. For 1980, Battelle is currently working on such an estimate, taking into account the energy supply situation; however, results were not available in time for this study. Therefore, a best estimate was made on the basis that the use of coal would show a sharp rise, both from new boilers and conversion of existing units, with a smaller rise in oil consumption and a decrease in natural gas use. A rough guideline was the fuel breakdown given in Ref. 2-20 for 1950 when coal was widely used in industrial boilers. A further consideration was the greater tendency toward coal in large units compared to the smaller sizes.

With boiler capacities and fuel consumption estimates in hand, the emissions of NO_x, CO, and HC for 1968 and 1973 were calculated using the emission factors of Ref. 2-11. Emission factors for NO_x from gas-fired boilers, given in Ref. 2-11 for industrial boilers, range from 120 to 230 lb/10^6 cu ft from the smallest to the largest boilers. Rather than trying to interpolate and use multiple factors, an arithmetic average of 175 was applied to the total gas consumption. Since NO_x emissions from natural gas combustion represent only about 20 percent of the total, an error in using an average emission factor should not significantly affect the total emissions.

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[7] KPPH = thousands of pounds of steam per hour.

In estimating probable NO_x emission factors for 1980, it was noted that there are currently no NO_x regulations for industrial boilers other than for new units larger than 250 million Btu/hr heat input but that some sort of control appears likely in the near future. Much of the NO_x control technology developed for utility boilers should be directly applicable, but the larger question concerns the degree to which new regulations will be met in industrial boilers by 1980. For the 1980 projections, it was assumed that the NO_x emission factors for coal firings will be reduced by 25 percent (as in the case of utility boilers) but that NO_x emissions from gas and oil-firings will be reduced by 50 percent, rather than the 58 to 65 percent reduction which appears likely for utility boilers. A summary of the 1973 NO_x emission factors and those assumed in this study for 1980, for both utility and industrial boilers, is as follows:

			Emission Factor			
			Utilities		Industrial	
Fuel	Emission Factor Unit	Use	1973	1980	1973	1980
Coal	lb/ton	General	18	13.5	18	13.5
	lb/ton	Cyclone	55	41	55	41
	lb/ton	Stoker	-	-	15	11.25
Oil	lb/1000 gal	Tangential	50	36	40	20
	lb/1000 gal	Other	105	36	80	40
Natural Gas	lb/million cu ft	Tangential	300	250	180	90
	lb/million cu ft	Other	600	250	180	90

As in the utility boiler category, HC and CO emissions were considered currently satisfactory, and the 1980 emissions factor used were unchanged from those of Ref. 2-11.

2.4.3 PART Emissions from Utility and Industrial Boilers

The PART emission category is different from those of NO_x, CO, and HC in that PART emissions are not only a function of the fuel type but are also strongly dependent on the PART control equipment used. PART emissions from gas- and oil-fired utility and industrial boilers represent less than seven percent of the total from these sources. As a result, only PART emissions from coal-fired boilers were examined in detail. For these coal-fired boilers, the PART emission factors can be classified in the general pulverized coal category and the more specific firing categories of stoker and cyclone. For each of these categories, the annual PART emissions can be calculated from the product of five factors: (1) coal usage rates, (2) average weight percent of ash in the coal, (3) ash factors, (4) average collector efficiencies, and (5) fraction of total plants using the collectors to control PART emissions. Data for each of these factors were obtained, respectively, from (1) the reference sources and analyses discussed in the previous sections plus Refs. 2-22 through 2-25 in the utility boiler area, (2) Ref. 2-21, (3) Ref. 2-11, (4) Ref. 2-21, and (5) Ref. 2-25 for utility boilers and Ref. 2-21 for industrial boilers. The values of percent ash, ash factors, collector efficiencies and control application [factors (2) through (5)] used to calculate 1967 to 1973 PART emissions in this analysis were as follows:

Boiler Type	Ash Factor[a]	% Ash	Collector Efficiency	Control Application	Net Control
Utility Boilers					
Pulverized	16	11.9	0.92	0.97	0.89
Stoker	13	11.2	0.80	0.87	0.70
Cyclone	3	11.8	0.91	0.79	0.72
Industrial Boilers					
Pulverized	16	10.6	0.85	0.95	0.81
Stoker	13	10.2	0.85	0.62	0.53
Cyclone	3	10.3	0.82	0.91	0.75

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[a] The ash factor multiplied by the percent of ash yields the uncontrolled emission factor.

For projections to 1980 in the utility boiler area, the assumption, based on data in Ref. 2-23, was that new construction would be 85 percent of the pulverized category, 15 percent of the cyclone firing type, and no new stoker construction. Application of control equipment to new construction was assumed to be 100 percent.

In the industrial boiler area, EPA standards of performance for new stationary sources (Ref. 2-26) require control efficiencies of about 0.988 (based on allowable emissions of 0.1 lb/million Btu and an average coal ash content of 10.4 percent), but these standards currently apply only to boilers with a capacity greater than 250 million Btu/hr heat input. It was assumed, therefore, that all new construction of boilers greater than 250 million Btu/hr capacity would be 100 percent controlled by the efficiency rate of 0.988. No regulations for industrial boilers of smaller capacity are currently forecast, and the control efficiencies and application (net control) therefore, were assumed to be the same in 1980 as in 1973.

Since PART emissions from gas- and oil-fired boilers, both utility and industrial, together represent a small fraction of those from coal-fired boilers, little effort was made to estimate changes in control efficiencies or control applications. Even on the assumption of 100 percent uncontrolled gas- and oil-fired utility and industrial boilers, the PART emissions from gas- and oil-firing projected to 1980 represent less than 7 percent of the projected total from these sources. PART emissions from gas- and oil-fired utility boilers were considered uncontrolled in all time periods. Controls for industrial boilers were treated the same except that new construction in the capacity range greater than 250 million Btu/hr were assumed to meet the EPA standards of performance for new stationary sources as given in Ref. 2-26.

2.5 NEDS DATA ANALYSIS

The NEDS data are stored in a large number of SCC by type of source (external combustion boiler, electric generation and industrial), by fuel (e.g., bituminous coal, lignite), and to some degree by firing types (e.g., pulverized wet, cyclone, stoker) (Table A.2 of Ref. 2-3). These data represent a more detailed breakdown than was available in the literature for the boilers of this study. The NEDS data also contain a large amount of detail on primary and secondary PART control equipment, categorized by control equipment identification codes (Table A.3 of Ref. 2-3), which does not appear to be available anywhere else. For these reasons, it was considered desirable to obtain a magnetic tape of data stored in the NEDS system for analysis. The availability of these in-house data on tape allowed extensive computer analysis and represents a powerful tool for emission inventories and other studies. A comparison of some of the totals, such as fuel usage and emissions, with data from other sources indicated that the NEDS data were considerably more comprehensive. In all cases, totals from various sources agreed as well as can be expected with the NEDS data. The NEDS data were initially accumulated and stored over the time period from about 1969 to 1972. Data available from other sources tend to represent time periods from about 1968 to 1973. Comparing the NEDS data with interpolated data for the same time period and considering the probable accuracies of these other sources, the NEDS data appear to be in good agreement.

Two significant problems with the NEDS tape data were found during this study. Significant errors of unknown origin can exist in some of the stored data. It appears that a single individual can submit data that are grossly in error and this error can enter into and remain in the NEDS data bank, undetected, grossly affecting all summary uses of the data. Annual CO emissions from coal-fired utility boilers were found to be more than a factor of five (more than 3×10^6 tons) too high. Two individuals submitting data in the process gas combustion area may have entered fuel usage data (total of several point sources within their plant) which were too high by factors of as much as 1000 (a total error of more than 2×10^{13} cu ft/yr). Such excessively high values can be detected with relative ease by screening the data for charge rates (fuel usage) larger than that of a very large plant. For excessively small values, however, Aerospace was unable to develop reliable, consistent methods for detecting errors or even to assure that zero values were not valid. The best overall checks found in this study involved correcting excessively high values and comparing the corrected totals against data from other sources, if available. These problems led to rather large estimates of the uncertainty of the final data.

The data stored in the NEDS were generated by many primary sources over a period of several years. In many cases, the emissions recorded were calculated from fuel usage rates and the then-current listing of emission factors. Most of the emission factors used in compiling the NEDS data are listed in the 1972 compilation (Ref. 2-27). From the 1972 compilation to the 1973 compilation (Ref. 2-11), there were some very large changes. Those important to this study are listed below:

Fuel	Plant Type	Emission	Emission Factor Ratio, 1973/1972
Coal	None	-	-
Oil	Utility	CO	75.0
	Industrial	CO	20.0
Natural Gas	Utility	NO_x	1.538
	Utility	HC	0.025
	Utility	CO	47.5
	Industrial	HC	0.075
	Industrial	CO	42.5

The changes in emission factors between these two compilations do not represent real changes in emissions but are more likely errors in the 1972 compilation, the first of its kind ever issued. In some cases, the emissions found in the NEDS tape data analyses could be brought into line with data from other sources by applying the above emission factor corrections. In the case of CO from all fuels, however, the emission totals from the NEDS tape analysis could not be brought into agreement with either the other sources in the literature or the NEDS nationwide emissions reports, even when these corrections were made.

Because of these problems, only the NEDS data which could be roughly verified by some other source were used. Similarly, because of the questions concerning the proper emission factors, the recorded NEDS emission data were not used as such. Instead, the NEDS fuel usage data were multiplied by 1973 emission factors obtained from Ref. 2-11. A check of resulting emissions totals calculated in this manner showed reasonably good agreement with direct NEDS emissions data, except as discussed in the CO and the process gas category.

A further complication in using the NEDS point source data (NEDS tape) results from the use of a number of fuels, concurrently or at different times, in the same facility. The emissions, operating times, PART control equipment, and compliance data (card nos. 3 through 5) are combined, listed, and stored as single values for the facility, while fuel and fuel usage data are listed separately by fuel (multiple cards no. 6). There appears to be no way to determine those emissions or fractions of operating time associated with each fuel. To generate total emissions data from the NEDS tape, this study utilized data from facilities using only one fuel (single card no. 6) to determine an effective emission factor for that SCC. Total emissions for that fuel were then calculated from the total usage of that fuel in that SCC. This procedure assumes that the emission factor for a given fuel in a given facility is the same whether or not the facility operates with multiple fuels. For example, there is some evidence in the literature that NO_x emissions during gas firing may be higher for a significant period of operation if it was preceded by a period of oil firing. No solution for this possible source of error was found.

One of the greatest values of the NEDS tape analysis is in the extremely detailed breakdown of PART control equipment usage and performance. No other source of such detail in the use of PART control equipment was identified. The data on the NEDS tape are such that further valuable information such as collector efficiencies, degree of application, and use of secondary collectors could also be developed. While such data were not of interest to the current study, it appears that a powerful tool for further data analysis is available.

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SECTION 3

STATIONARY INTERNAL COMBUSTION ENGINES

3.1 INTRODUCTION

Stationary internal combustion (IC) engines include those used for (1) electrical power generation, (2) industrial use, (3) commercial and institutional application, and (4) engine testing. The fuels used in these engines range from natural gas to crude oil. The types of engines include diesel and spark ignition reciprocating engines and gas turbines.

Since by definition point source engines are those where one or more of the common emissions exceed 100 tons per year, it is to be expected that many stationary engines fall into the area source category (all stationary sources of pollution other than point sources). These engines fail to qualify as point source engines because of (1) a smallness in size, (2) a low usage rate, (3) a low emission factor, or (4) a combination of these factors.

Although the emissions total (point source plus area source) for most types of stationary engines is not much larger than point source only, four engine-fuel combinations were identified where area source emissions are estimated to be significantly large simply because their populations are enormous. These four engines are distillate-fueled and crude-oil-fueled turbines and gasoline-fueled and diesel-fueled reciprocating engines.

This study concentrates on point sources of air pollution as described in Section 3.3; Section 3.4 describes the assessment of the engine categories that make significant contributions to both area and point source emissions.

3.2 SUMMARY

The point source stationary IC engines studied along with their modified source classification code (MSCC) numbers and MSCC charge rate units are listed in Table 3-1. The 1975 point source charge rates and emissions used as a data base are shown in Table 3-2-a and their uncertainties in Table 3-2-b. The 1980 estimated charge rates and point source emissions are shown in Table 3-3-a, with uncertainties in Table 3-3-b.

Point source IC engines in 1980 will contribute about one-half million tons per year of nitrogen oxides (NO_x) and hydrocarbons (HC) and about 60,000 tons of carbon monoxide (CO) annually. The annual area source emissions for the four previously mentioned engines are estimated to be about 3 million tons of NO_x, 1 million tons of HC, and about 13.5 million tons of CO. The largest contributor to stationary IC engine pollution is the conventional gasoline engine.

3.3 POINT SOURCES

This category includes fixed installations of diesel and spark ignition reciprocating engines and gas turbine engines. These engines are used for electrical power generation and for industrial use such as pumps for fuels, water, and sewage and compressors for gaseous fuels and air. The three basic types of engines may be further subdivided into subtypes such as two and four stroke, direct and indirect injection, and carburetion.

However, obtaining emissions from such breakdowns is frustrated by a lack of a breakdown in annual fuel consumption and emission factors by engine subtype. Thus, it is not possible to establish the effect on the environment of variations in engine configuration, state of repair, or specific application. Significant pollution contributors in this category are listed in Table 3-1.

3.3.1 Diesel Engines

Diesel engines are used for electrical generation in oil and gas pipelines, oil and gas exploration, and pumping water and sewage.

(Continued on page 3-10)

Table 3-1. DEFINITION OF INTERNAL COMBUSTION PROCESSES

MSCC	Source Category	Charge Rate Unit
201000000	Internal Combustion (Electrical Generating)	
201001010	Distillate-oil-fueled turbine	1000 gal/yr
201002010	Natural-gas-fueled turbine	Million cu ft/yr
201002020	Natural-gas-fueled reciprocating	Million cu ft/yr
201003010	Diesel-fueled reciprocating	1000 gal/yr
201999970	Other, not classified	Million cu ft/yr
201999980	Other (not classified)	1000 gal/yr
202000000	Internal Combustion (Industrial)	
202001010	Distillate-oil-fueled turbine	1000 gal/yr
202002010	Natural gas turbine	Million cu ft/yr
202002020	Natural gas reciprocating	Million cu ft/yr
202003010	Gasoline reciprocating	1000 gal/yr
202004010	Diesel reciprocating	1000 gal/yr
202999970	Other (not classified)	Million cu ft/yr

Table 3-2-a. 1975 INTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

```
                         INTERNAL COMBUSTION ENGINES                     PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975     RUN DATE=JUNE 24,1976
 MODIFIED         TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX            HC             CO            PART

201001000        1088100.           .120           .002           .010           .008

201001010        1088100.           .120           .002           .010           .008

201002000         338860.           .096           .001           .000           .000

201002010         115840.           .020           .001           .000           .000
201002020         223020.           .076          0.000          0.000          0.000

201003000          75159.           .011           .001           .005           .002

201003010          75159.           .011           .001           .005           .002

201999000                           .017           .083           .002           .001

201999970           7258.           .011           .012          0.000          0.000
201999980         115600.           .006           .072           .002           .001

202001000          65953.           .004           .000           .002           .001

202001010          65953.           .004           .000           .002           .001

202002000         973960.           .348           .089           .044           .004

202002010          69322.           .011           .003           .003           .000
202002020         904640.           .337           .066           .041           .004

202003000           3470.           .000           .000           .003           .000

202003010           3470.           .000           .000           .003           .000

202004000          26201.           .005           .000           .002           .000

202004010          26201.           .005           .000           .002           .000

202999000          23828.           .003           .172           .001           .000

202999970          23828.           .003           .172           .001           .000
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Table 3-2-b. 1975 INTERNAL COMBUSTION UNCERTAINTIES

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                                 INTERNAL COMBUSTION ENGINES                      PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975       RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX            HC             CO           PART

201001000   +    3320600.      +  .369      +  .005      +  .029      +  .024
            -    1088100.      -  .120      -  .002      -  .010      -  .008

201001010   +    3320600.      +  .369      +  .005      +  .029      +  .024
            -    1088100.      -  .120      -  .002      -  .010      -  .008

201002000   +     417670.      +  .072      +  .002      +  .003      +  .001
            -     118200.      -  .022      -  .001      -  .000      -  .000

201002010   +     417010.      +  .072      +  .002      +  .003      +  .001
            -     115840.      -  .020      -  .001      -  .000      -  .000
201002020   +      23532.      +  .008      + 0.000      + 0.000      + 0.000
            -      23532.      -  .008      - 0.000      - 0.000      - 0.000

201003000   +      14799.      +  .003      +  .000      +  .002      +  .001
            -      14799.      -  .002      -  .000      -  .001      -  .001

201003010   +      14799.      +  .003      +  .000      +  .002      +  .001
            -      14799.      -  .002      -  .000      -  .001      -  .001

201999000                      +  .003      +  .012      +  .000      +  .001
                               -  .003      -  .012      -  .000      -  .001

201999970   +       1804.      +  .003      +  .003      + 0.000      + 0.000
            -       1804.      -  .003      -  .003      - 0.000      - 0.000
201999980   +      18027.      +  .001      +  .011      +  .000      +  .001
            -      18027.      -  .001      -  .011      -  .000      -  .001

202001000   +      22224.      +  .001      +  .000      +  .001      +  .000
            -      22224.      -  .001      -  .000      -  .001      -  .000

202001010   +      22224.      +  .001      +  .000      +  .001      +  .000
            -      22224.      -  .001      -  .000      -  .001      -  .000

202002000   +     616740.      +  .111      +  .030      +  .024      +  .005
            -     174900.      -  .061      -  .016      -  .008      -  .004
```

Table 3-2-b. 1975 INTERNAL COMBUSTION UNCERTAINTIES (Continued)

INTERNAL COMBUSTION ENGINES PAGE 2

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)		EMISSIONS (MILLIONS OF TONS / YEAR) NOX		HC		CO		PART
202002010	+	595470.	+	.094	+	.024	+	.022	+	.004
	-	69322.	-	.011	-	.003	-	.003	-	.000
202002020	+	160580.	+	.060	+	.018	+	.008	+	.004
	-	160580.	-	.060	-	.015	-	.007	-	.004
202003000	+	1172.	+	.000	+	.000	+	.002	+	.000
	-	1172.	-	.000	-	.000	-	.001	-	.000
202003010	+	1172.	+	.000	+	.000	+	.002	+	.000
	-	1172.	-	.000	-	.000	-	.001	-	.000
202004000	+	26055.	+	.005	+	.000	+	.002	+	.000
	-	26055.	-	.005	-	.000	-	.002	-	.000
202004010	+	26055.	+	.005	+	.000	+	.002	+	.000
	-	26055.	-	.005	-	.000	-	.002	-	.000
202999000	+	5925.	+	.001	+	.175	+	.000	+	.000
	-	5925.	-	.001	-	.043	-	.000	-	.000
202999970	+	5925.	+	.001	+	.175	+	.000	+	.000
	-	5925.	-	.001	-	.043	-	.000	-	.000

Table 3-3-a. 1980 INTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

INTERNAL COMBUSTION ENGINES PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
201001000	1275600.	.141	.002	.011	.009
201001010	1275600.	.141	.002	.011	.009
201002000	290630.	.083	.000	.000	.000
201002010	98582.	.017	.000	.000	.000
201002020	192050.	.066	0.000	0.000	0.000
201003000	82909.	.012	.001	.005	.002
201003010	82909.	.012	.001	.005	.002
201999000		.019	.100	.002	.002
201999970	8089.	.012	.013	0.000	0.000
201999980	140600.	.007	.087	.002	.002
202001000	79753.	.005	.000	.002	.001
202001010	79753.	.005	.000	.002	.001
202002000	824330.	.297	.076	.037	.004
202002010	48187.	.008	.002	.002	.000
202002020	776140.	.289	.074	.035	.003
202003000	4627.	.001	.001	.004	.000
202003010	4627.	.001	.001	.004	.000
202004000	35626.	.006	.000	.003	.000
202004010	35626.	.006	.000	.003	.000
202999000	32923.	.005	.237	.001	.000
202999970	32923.	.005	.237	.001	.000

Table 3-3-b. 1980 INTERNAL COMBUSTION UNCERTAINTIES

```
                              INTERNAL COMBUSTION ENGINES                        PAGE  1
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980      RUN DATE=JUNE 24,1976
  MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)          NOX             HC              CO             PART
 201001000   +     3472000.       +  .387       +  .005       +  .030       +  .025
             -     1275600.       -  .141       -  .002       -  .011       -  .009

 201001010   +     3472000.       +  .387       +  .005       +  .030       +  .025
             -     1275600.       -  .141       -  .002       -  .011       -  .009

 201002000   +      419680.       +  .074       +  .002       +  .003       +  .001
             -      109070.       -  .023       -  .000       -  .000       -  .000

 201002010   +      417070.       +  .072       +  .002       +  .003       +  .001
             -       98582.       -  .017       -  .000       -  .000       -  .000
 201002020   +       46677.       +  .016       + 0.000       + 0.000       + 0.000
             -       46677.       -  .016       - 0.000       - 0.000       - 0.000

 201003000   +       18635.       +  .003       +  .000       +  .002       +  .001
             -       18635.       -  .003       -  .000       -  .001       -  .001

 201003010   +       18635.       +  .003       +  .000       +  .002       +  .001
             -       18635.       -  .003       -  .000       -  .001       -  .001

 201999000                        +  .005       +  .026       +  .001       +  .001
                                  -  .005       -  .026       -  .001       -  .001

 201999970   +        3163.       +  .005       +  .005       + 0.000       + 0.000
             -        3163.       -  .005       -  .005       - 0.000       - 0.000
 201999980   +       41231.       +  .002       +  .026       +  .001       +  .001
             -       41231.       -  .002       -  .026       -  .001       -  .001

 202001000   +       49437.       +  .003       +  .000       +  .001       +  .001
             -       49437.       -  .003       -  .000       -  .001       -  .001

 202001010   +       49437.       +  .003       +  .000       +  .001       +  .001
             -       49437.       -  .003       -  .000       -  .001       -  .001

 202002000   +      662170.       +  .139       +  .037       +  .026       +  .005
             -      276270.       -  .102       -  .026       -  .013       -  .003
```

Table 3-3-b. 1980 INTERNAL COMBUSTION UNCERTAINTIES (Continued)

```
                               INTERNAL COMBUSTION ENGINES                        PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980       RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX               HC                CO             PART

202002010    +      603710.     +  .095      +  .025      +  .022      +  .004
             -       48187.     -  .008      -  .002      -  .002      -  .000
202002020    +      272030.     +  .101      +  .027      +  .013      +  .003
             -      272030.     -  .101      -  .026      -  .012      -  .003

202003000    +        2311.     +  .000      +  .000      +  .003      +  .000
             -        2311.     -  .000      -  .000      -  .002      -  .000

202003010    +        2311.     +  .000      +  .000      +  .003      +  .000
             -        2311.     -  .000      -  .000      -  .002      -  .000

202004000    +       26452.     +  .005      +  .000      +  .002      +  .000
             -       26452.     -  .005      -  .000      -  .002      -  .000

202004010    +       26452.     +  .005      +  .000      +  .002      +  .000
             -       26452.     -  .005      -  .000      -  .002      -  .000

202999000    +       14845.     +  .002      +  .258      +  .001      +  .000
             -       14845.     -  .002      -  .107      -  .001      -  .000

202999970    +       14845.     +  .002      +  .258      +  .001      +  .000
             -       14845.     -  .002      -  .107      -  .001      -  .000
```

For electrical generation, diesel engines represent on the order of 1.2 percent of the 1970 total electrical generating capacity in the United States and only about 0.3 percent of the total power generated, for an average utilization of about 12 percent. These engines are used for electrical peaking power and also standby installation. The projected utilization factor for 1980 drops to eight percent.

Diesel engines represent about four percent of the installed horsepower in pipelines and about five percent of the power generated. For oil and gas exploration, about 75 percent of the power used is generated by diesel engines. For municipal water and sewage pumping about 50 percent is diesel-powered, while agricultural water pumping is done almost exclusively by diesel engines.

3.3.2 Gas Turbines

The main applications for stationary gas turbines include electric power generation for utilities and for industrial and pipeline use. Gas turbines have low initial costs, short delivery times, small space requirements, flexible fuel needs, and high thermal efficiency. For these reasons, turbines are being installed in electrical plants to replace steam plants or to add capacity.

Gas turbine engines vary greatly in size and configuration. Turbines have single- or two-shaft designs. Both types can be operated in simple cycles, regenerative cycles, or combined cycles. The simple-cycle engines operate at 25 to 30 percent efficiency. Regenerative cycles utilize a heat exchanger which uses turbine exhaust gases to heat the air as it passes from the compressor into the combustor. Efficiency of these engines runs about 34 to 38 percent. In the combined cycle, turbine exhaust gas is used to generate steam which drives a second generator or other device. Efficiencies of 40 to 42 percent are realized with these units.

3.3.3 Spark Ignition Engines

The spark ignition internal combustion engine is the most widely used powerplant in the world today. These engines range from small single-cylinder units producing as little as a fraction of a horsepower to large multicylinder units with power ratings of several thousand horsepower. The large units are predominantly used in stationary power applications.

Medium-sized gasoline engines (50 to 200 hp) are used for commercial and construction site compressors, pumps, blowers, and electric power generators. Medium-large spark ignition engines (200 to 1000 hp) are generally operated on gaseous fuels to power gas compressors or standby power generators. Large spark ignition engines (greater than 1000 hp) always operate on gaseous fuels and are used for gas-well recompression, gas plant compressors, refinery process compressors, water and sewage pumping, and continuous electrical power generation.

3.3.4 Charge Rate

The NEDS was used as the primary source of data. Annual charge rates (fuel consumption), as of the year of record, formed the starting point for the charge rate projections.

The rate of change of charge rate for electric utility turbines is based on the fuel demand data shown in Figure 3-1. The total rises every year for all fuels except natural gas, reflecting the increased dependence on turbine power. Lacking fuel consumption projections on gas turbines for industrial use, the assumption was made that charge rate trends for these turbines are equal to those for electrical power demand. For turbines used in the handling of petroleum products in such services as pumping and pressurization, it is also reasonable to assume that the same trends exist as for the electric utility consumers.

For reciprocating engines, it was necessary to use less direct methods of estimating charge rate changes. Table 3-4 shows data on the number of IC engines versus end use for gasoline and diesel fuels. Only those listed in the source (Ref. 3-4) for construction, generator sets, or general industrial use were considered in this part of the study. Of the engines produced (Table 3-4), many were probably for replacement of

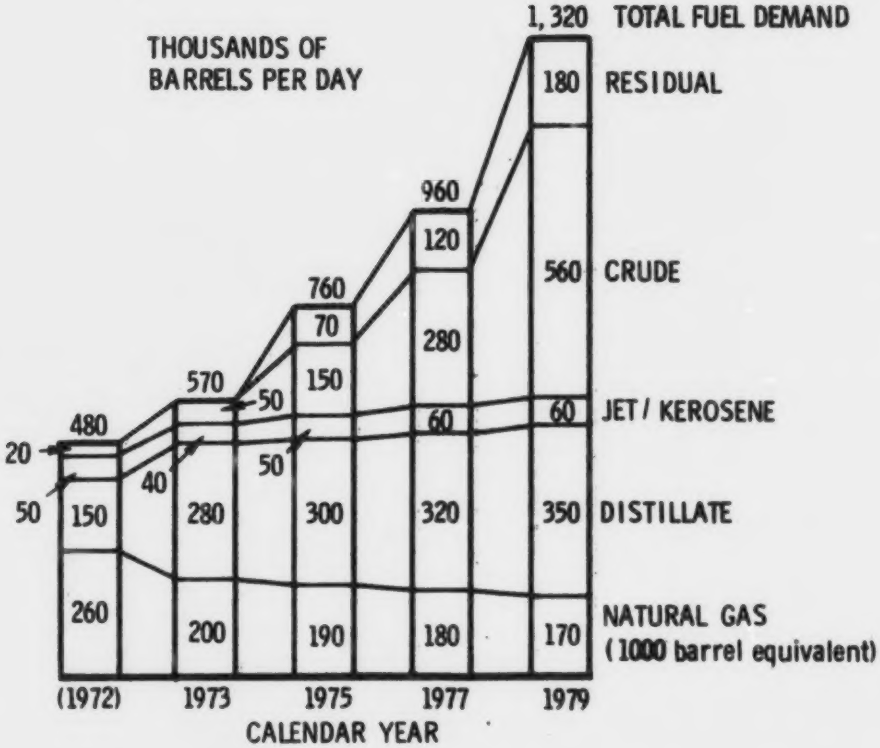

Figure 3-1. Electric utility gas turbine fuel demand

Table 3-4. INTERNAL COMBUSTION ENGINE DISTRIBUTION: NUMBER VERSUS END USE

Engine Type and End Use[a]	Number of IC Engines Distributed[b]									
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Gasoline										
Construction and General Industrial Use	1,172,836	1,306,153	1,192,112	1,239,276	1,424,790	1,225,742	1,174,173	975,637	1,399,800	1,272,551
Generator Sets	67,769	76,678	67,930	67,798	90,760	86,264	104,142	146,270	165,183	176,014
Total Gasoline	1,240,605	1,382,831	1,260,042	1,307,074	1,515,550	1,312,006	1,278,320	1,121,907	1,564,983	1,448,565
Diesel										
Construction and General Industrial Use	130,185	140,021	134,665	139,577	156,329	142,266	130,216	150,823	175,071	200,054
Generator Sets	13,209	12,746	5,564	6,070	8,535	10,201	8,400	9,661	13,327	15,212
Total Diesel	143,394	152,767	140,299	145,647	164,864	152,467	138,616	160,484	188,398	215,266
Total IC Engines	1,383,999	1,535,598	1,400,271	1,452,721	1,680,414	1,464,473	1,416,936	1,282,991	1,753,381	1,663,831

[a] Ref. 3-4.

[b] Represents total number of engines shipped or produced and incorporated into products at the same establishment during the time period 1965 through 1974.

worn-out engines or were exported, with perhaps only 10 percent of production going into new installations. Hence, the assumption of a change of charge rate based on 10 percent of the annual production seems conservative, but the uncertainty of this slope is rather large. Comparison of several sources of predicted consumption for electrical generation shows variations in slopes of from 3 to 22 percent per year. Thus, a 10 percent slope with 10 percent uncertainty in the slope was assumed.

3.3.5 Emission Factors

The emission factors were derived from the NEDS data by dividing the emissions by the charge rate. Other sources of emission factors (Refs. 3-1 through 3-3) were used to determine the uncertainty of the NEDS data. It was assumed that emission factors would not change with the passage of time. The only factor that would change that assumption would be the imposition of clean air standards on all of the users of this equipment. This factor was ignored in the data input; thus, the data represent emissions with no controls imposed.

3.3.6 Results

Table 3-3-a shows the 1980 projections of annual charge rates and emissions for point sources. The data show that about one-half million tons per year of NO_x and HC are produced by stationary IC engines. Of this amount, about 50 percent of the NO_x and 20 percent of the HC are from electrical generating plants, with the remainder from industrial sources. In the electrical generating category, the worst offender is the distillate-fueled gas turbine. With a charge rate of over 1.25 billion gal/year, it contributes about 140,000 tons/year of NO_x. In the industrial use classification, natural gas reciprocating engines contribute about 300,000 tons/year of NO_x from about 780 billion cu ft/year of gas. The uncertainty in 1980 charge rates and emissions are shown in Table 3-3-b.

3.4 TOTAL EMISSIONS FROM SELECTED STATIONARY IC ENGINES (POINT AND AREA SOURCES)

3.4.1 Introduction

As reported in Section 3.1, four stationary IC engine-fuel combinations were identified whose total (area plus point source) emissions far exceed the estimated point source emissions reported in Section 3.3. The four offenders are distillate-fueled and crude-oil-fueled turbines, and gasoline-fueled and diesel-fueled reciprocating engines. Identification of the engine types responsible for these large area source emissions was possible through analysis of the data extracted from Refs. 3-1, 3-4, and 3-5. This section reports the rationale and results of estimating the total emissions for those four types of engines.

3.4.2 Summary

Four engine-fuel combinations were found to contribute potentially significant amounts of area source pollution: distillate-fueled and crude-oil-fueled turbines and gasoline-based and diesel-fueled reciprocating engines. Table 3-5 shows the total emissions for these engines in 1980. Table 3-6 gives the 1980 projection of pollutants from these four sources in excess of the point sources data reported in Section 3.3.

3.4.3 Discussion

3.4.3.1 Turbines

In 1971, the installed horsepower for gas turbines was about 38 million. About 29 million of that was for electrical power generation, and the remainder was for pipelines and natural gas processing. For power generation, gas turbines provide the repowering when old and less efficient plants are retired and also fill the need for increased power. In 1970, approximately 5 percent of the power generated was by gas turbines; by 1980, it is estimated that as much as 12 percent of the power capacity will be from gas turbines. Projected electrical generation use is about 120-million hp in

Table 3-5. 1980 PROJECTION OF TOTAL INTERNAL COMBUSTION ENGINE EMISSIONS[a]

Source Category	Emissions, million tons/yr			Charge Rate, 1000 gal/yr
	NO_x	HC	CO	
Distillate-Fueled Turbines	0.459	0.011	0.060	6.70×10^6
Crude-Oil-Fueled Turbines	0.884	0.022	0.116	12.90×10^6
Gasoline-Fueled Reciprocating Engines	1.345	0.924	13,273	12.75×10^6
Diesel-Fueled Reciprocating Engines	0.432	0.032	0.142	2.40×10^6
Total	3.120	0.989	13.591	34.75×10^6

[a] Point source and area source emissions.

Table 3-6. 1980 PROJECTION OF AREA SOURCE INTERNAL COMBUSTION ENGINE EMISSIONS

Source Category	Emissions, million tons/yr			Charge Rate, 1000 gal/yr
	NO_x	HC	CO	
Distillate-Fueled Turbines	0.313	0.009	0.047	5.34×10^6
Crude-Oil-Fueled Turbines	0.884	0.022	0.116	12.90×10^6
Gasoline-Fueled Reciprocating Engines	1.344	0.923	13.269	12.74×10^6
Diesel-Fueled Reciprocating Engines	0.414	0.031	0.134	2.28×10^6
Total	2.955	0.985	13.566	33.26×10^6

1980. Similar growth rates for other uses can be expected. By 1980, therefore, total gas turbine installed horsepower will be on the order of 150 million.

Figure 3-1 shows distillate consumption for gas turbines for electrical generation growing to 350,000 bbl (14.7-million gal/day in 1979). Projecting this to 1980, fuel consumption can be expected to be 5.6-billion gal/year for electrical generation alone. Adding consumption for other uses increases this number by 20 percent to 6.7-billion gal/year. The 1979 crude oil demand from Figure 3-1 is 560,000 bbl (23.52-million gal/day). Projecting the growth rate to 1980 and adding 20 percent for uses other than electrical generation, the estimated consumption of crude oil in gas turbines will be 12.9-billion gal/year in 1980.

Emission factors used to estimate total emissions are the average of emission factors derived from the NEDS data and from Refs. 3-1 through 3-3. Crude oil emission factors were assumed to be the same as the distillate emission factors, in the absence of any other information.

3.4.3.2 Diesel Engines

In Ref. 3-1, the total estimated installed horsepower of stationary diesel engines was about 16-million bhp (brake horsepower) in 1971. Of this total, 5.2-million bhp were used for electrical generation, and the remainder was for industrial uses.

Table 3-4 indicates that about 215,000 diesel engines for industrial construction and generator sets were shipped in 1974. Total horsepower was about 42 million for engines of greater than 50 hp. To estimate fuel consumption, it was necessary to make the following assumptions:

a. Twenty percent of the engines shipped were new installations. The remainder were replacement engines or were exported (nine percent were exported in 1974).

b. Engines will be operated on an average of 1170 hr/year. NEDS data for 1970 indicate an average of 1888 hr/year for electrical generation and 5282 hr/year for industrial use. The estimated 1980 operation is 8 percent for electrical generation and 15 percent for industrial use.

c. Specific fuel consumption is 0.40 lb/bhp-hr. (According to Ref. 3-1, an average specific fuel consumption is 0.403 for diesels of this class.) Using data from Ref. 3-4 and the 1974 growth rate, it is estimated that diesel horsepower will be about 36 million in 1980; fuel consumption will be 2.40-billion gal/year (7.0 lb/gal). Emission factors were derived as for gas turbines (Section 3.3.5).

3.4.3.3 Spark Ignition Engines

Spark ignition engines, both liquid- and gaseous-fueled, are by two orders of magnitude the most common engines in the country today. The 1971 total installed horsepower is estimated at 800-million (Ref. 3-1). These engines are used for everything from small power tools to 1000-hp and greater compressors, pumps, and electrical power installations.

Table 3-4 shows the number of IC engines shipped in the years 1965 to 1974. Gasoline engines for construction, general industrial use, and electrical generator sets number well over one million in each of those years. Assuming that the engines in these categories are the larger horsepower rated engines, this represents about 50-million hp/year. Of the 800-million hp in 1971, it is estimated that about 50 percent was devoted to these categories.

Using the same assumptions as were made for diesel engines, namely, that 20 percent were new installations, but now assuming the average engine is used for 300 hr/year, the 1980 estimated installed horsepower is 490 million and the annual fuel consumption (at 0.52 lb/bhp-hr) is 12.75-billion-gal/year. Gasoline density of 6.0 lb/gal was used in this computation.

Emission factors were derived by the same method used for gas turbines (Section 3.3.5).

3.4.3.4 Results and Conclusions

From charge rates and emission factors, the 1980 total emissions were estimated and are presented in Table 3-5. The data indicate that about 3-million tons of NO_x, 1-million tons of HC, and 13.6-million tons of CO (mainly from gasoline engines) will be emitted from these engines. Table 3-6 is the same data minus the point source data in Table 3-3-a. This shows an estimate of the area source pollution.

The uncertainty of the data is large. Although the assumptions made are thought to be conservative, the real contribution of these engines could be much higher.

The conclusions to be drawn from this study are that a large number of stationary IC engines are being produced in this country every year and that information as to the application and utilization rates of these engines is lacking. Therefore, a potentially large source of air pollution is going undetected. Efforts to trace these engines to the user and to estimate numbers of engines, use rate, and emissions are recommended.

3.5 REFERENCES

3-1. W. U. Roessler, et al., Assessment of the Applicability of Automotive Emission Control Technology to Stationary Engines, EPA-650/2-74-051, The Aerospace Corporation, El Segundo, California (July 1974).

3-2. C. R. McGowin, Stationary Internal Combustion Engines in the United States, EPA-R2-73-210, Shell Development Company, Houston, Texas (April 1973).

3-3. NEDS Source Classification Codes and Emission Factor Listing (SCC Listing), Office of Air and Waste Material, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C. (July 1974).

3-4. "Internal Combustion Engines: 1965 through 1974," Current Industrial Reports Series, MA-35L (65 through 74)-1, U.S. Bureau of the Census, Washington, D.C. (1975).

3-5. V. DeBiasi, "Double Standard on Fuel Oils Would Favor Steam over Gas Turbine Plants," Gas Turbine World (September 1973).

SECTION 4

CHEMICAL MANUFACTURING

4.1 INTRODUCTION

The emission sources discussed in this section are classified under the general process category of chemical manufacturing and the more specific categories of carbon black and ammonia manufacturing. The emissions under consideration are oxides of nitrogen (NO_x), hydrocarbons (HC), carbon monoxide (CO), and particulate (PART) matter.

This section describes the development of the data base used to calculate emissions from chemical manufacturing. The development of emission equations is described in Section 1, Data Handling. Chemical manufacturing processes studies are defined according to the National Emissions Data System (NEDS) source classification codes (SCC) and, in Table 4-1, by the NEDS modified source classification code (MSCC) developed by The Aerospace Corporation for this study.

4.2 SUMMARY

Chemical manufacturing production rates and emissions are defined for 1975 and estimated for 1980. These data are respectively listed in Tables 4-2-a and 4-3-a. The uncertainties in the production and emission data are listed in Tables 4-2-b and 4-3-b for 1975 and 1980, respectively. Table 4-1 describes the process and production rate (charge rate) unit for each MSCC for which emissions were determined.

(Continued on page 4-9)

Table 4-1. DEFINITION OF CHEMICAL MANUFACTURING PROCESSES

MSCC	Source Category	Charge Rate Unit
301002010	Purge gas in ammonia plant with methanator	Tons/yr
301002020	Storage and loading in ammonia plant with methanator	↓
301003010	Regenerator exit in ammonia plant with CO absorber	↓
301003020	Purge gas in ammonia plant with CO absorber	↓
301003030	Storage and loading in ammonia plant with CO absorber	↓
301003990	Miscellaneous processes in ammonia plant with CO absorber	↓
301005010	Channel process carbon black production	↓
301005020	Thermal processes carbon black production	↓
301005030	Gas-fired furnace process carbon black production	↓
301005040	Oil-fired furnace process carbon black production	↓
301005050	Gas- and oil-fired furnace process carbon black production	↓
301005991	SIC 2952 sector of miscellaneous carbon black processes	↓
301005992	SIC 3624 sector of miscellaneous carbon black processes	↓
301005993	SIC 3999 sector of miscellaneous carbon black processes	↓
301005994	SIC 2899 sector of miscellaneous carbon black processes	↓
301005995	All other SICs of sector of miscellaneous carbon black processes	↓
301999991	SIC 2818 sector of miscellaneous chemical manufacturing	↓
301999992	SIC 3999 sector of miscellaneous chemical manufacturing	↓
301999993	All other SICs of sector of miscellaneous chemical manufacturing	↓

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[a] Standard industrial classification (SIC). The product description corresponding to each SIC is given in Ref. 4-1.

Table 4-2-a. 1975 CHEMICAL MANUFACTURING EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
301002000	6106000.	NEGLIGIBLE	.209	.003	NEGLIGIBLE
301002010	5235000.	NEGLIGIBLE	.209	.003	NEGLIGIBLE
301002020	871000.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301003000	2443000.	NEGLIGIBLE	.031	.046	NEGLIGIBLE
301003010	769000.	NEGLIGIBLE	.001	.046	NEGLIGIBLE
301003020	743000.	NEGLIGIBLE	.030	0.000	NEGLIGIBLE
301003030	555000.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301003990	376000.	NEGLIGIBLE	.000	0.000	NEGLIGIBLE
301005000	6054400.	NEGLIGIBLE	.322	2.241	NEGLIGIBLE
301005010	126700.	NEGLIGIBLE	.112	.508	NEGLIGIBLE
301005020	216800.	NEGLIGIBLE	.000	.003	NEGLIGIBLE
301005030	31800.	NEGLIGIBLE	.027	.084	NEGLIGIBLE
301005040	491400.	NEGLIGIBLE	.103	.552	NEGLIGIBLE
301005050	641100.	NEGLIGIBLE	.071	1.040	NEGLIGIBLE
301005990	4546600.	NEGLIGIBLE	.009	.055	NEGLIGIBLE
301005991	4003000.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301005992	425400.	NEGLIGIBLE	.004	.009	NEGLIGIBLE
301005993	24330.	NEGLIGIBLE	.005	.045	NEGLIGIBLE
301005994	44550.	NEGLIGIBLE	.000	.000	NEGLIGIBLE
301005995	49290.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301999000	151180000.	NEGLIGIBLE	.518	.336	NEGLIGIBLE
301999990	151180000.	NEGLIGIBLE	.518	.336	NEGLIGIBLE
301999991	70000000.	NEGLIGIBLE	.276	.067	NEGLIGIBLE
301999992	181500.	NEGLIGIBLE	.018	.153	NEGLIGIBLE
301999993	81000000.	NEGLIGIBLE	.224	.116	NEGLIGIBLE

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Table 4-2-b. 1975 CHEMICAL MANUFACTURING UNCERTAINTIES

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR)					
			NOX		HC		CO	PART
301002000	+	229110.	NEGLIGIBLE	+	.028	+	.001	NEGLIGIBLE
	-	229110.	NEGLIGIBLE	-	.028	-	.001	NEGLIGIBLE
301002010	+	226000.	NEGLIGIBLE	+	.028	+	.001	NEGLIGIBLE
	-	226000.	NEGLIGIBLE	-	.028	-	.001	NEGLIGIBLE
301002020	+	37599.	NEGLIGIBLE	+	0.000	+	0.000	NEGLIGIBLE
	-	37599.	NEGLIGIBLE	-	0.000	-	0.000	NEGLIGIBLE
301003000	+	54487.	NEGLIGIBLE	+	.004	+	.031	NEGLIGIBLE
	-	54487.	NEGLIGIBLE	-	.004	-	.031	NEGLIGIBLE
301003010	+	33199.	NEGLIGIBLE	+	.000	+	.031	NEGLIGIBLE
	-	33199.	NEGLIGIBLE	-	.000	-	.031	NEGLIGIBLE
301003020	+	32080.	NEGLIGIBLE	+	.004	+	0.000	NEGLIGIBLE
	-	32080.	NEGLIGIBLE	-	.004	-	0.000	NEGLIGIBLE
301003030	+	23960.	NEGLIGIBLE	+	0.000	+	0.000	NEGLIGIBLE
	-	23960.	NEGLIGIBLE	-	0.000	-	0.000	NEGLIGIBLE
301003990	+	16230.	NEGLIGIBLE	+	.000	+	0.000	NEGLIGIBLE
	-	16230.	NEGLIGIBLE	-	.000	-	0.000	NEGLIGIBLE
301005000	+	226540.	NEGLIGIBLE	+	.072	+	.340	NEGLIGIBLE
	-	226540.	NEGLIGIBLE	-	.072	-	.340	NEGLIGIBLE
301005010	+	79830.	NEGLIGIBLE	+	.071	+	.321	NEGLIGIBLE
	-	79830.	NEGLIGIBLE	-	.071	-	.321	NEGLIGIBLE
301005020	+	17799.	NEGLIGIBLE	+	.000	+	.000	NEGLIGIBLE
	-	17799.	NEGLIGIBLE	-	.000	-	.000	NEGLIGIBLE
301005030	+	2550.	NEGLIGIBLE	+	.003	+	.007	NEGLIGIBLE
	-	2550.	NEGLIGIBLE	-	.003	-	.007	NEGLIGIBLE
301005040	+	39400.	NEGLIGIBLE	+	.009	+	.052	NEGLIGIBLE
	-	39400.	NEGLIGIBLE	-	.009	-	.051	NEGLIGIBLE
301005050	+	51400.	NEGLIGIBLE	+	.007	+	.098	NEGLIGIBLE
	-	51400.	NEGLIGIBLE	-	.006	-	.098	NEGLIGIBLE
301005990	+	201070.	NEGLIGIBLE	+	.001	+	.005	NEGLIGIBLE
	-	201070.	NEGLIGIBLE	-	.001	-	.005	NEGLIGIBLE
301005991	+	200000.	NEGLIGIBLE	+	0.000	+	0.000	NEGLIGIBLE
	-	200000.	NEGLIGIBLE	-	0.000	-	0.000	NEGLIGIBLE

Table 4-2-b. 1975 CHEMICAL MANUFACTURING UNCERTAINTIES (Continued)

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                   INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING          PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980      RUN DATE=JUNE 24,1976
 MODIFIED         TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)         NOX             HC            CO         PART

301005992   +        19999.   NEGLIGIBLE    +   .000     +   .001    NEGLIGIBLE
            -        19999.   NEGLIGIBLE    -   .000     -   .001    NEGLIGIBLE
301005993   +         1000.   NEGLIGIBLE    +   .001     +   .005    NEGLIGIBLE
            -         1000.   NEGLIGIBLE    -   .001     -   .005    NEGLIGIBLE
301005994   +         2000.   NEGLIGIBLE    +   .000     +   .000    NEGLIGIBLE
            -         2000.   NEGLIGIBLE    -   .000     -   .000    NEGLIGIBLE
301005995   +         4999.   NEGLIGIBLE    + 0.000      + 0.000     NEGLIGIBLE
            -         4999.   NEGLIGIBLE    - 0.000      - 0.000     NEGLIGIBLE

301999000   +     17464000.   NEGLIGIBLE    +   .065     +   .129    NEGLIGIBLE
            -     17464000.   NEGLIGIBLE    -   .065     -   .129    NEGLIGIBLE

301999990   +     17464000.   NEGLIGIBLE    +   .065     +   .129    NEGLIGIBLE
            -     17464000.   NEGLIGIBLE    -   .065     -   .129    NEGLIGIBLE

301999991   +      7000000.   NEGLIGIBLE    +   .039     +   .010    NEGLIGIBLE
            -      7000000.   NEGLIGIBLE    -   .039     -   .010    NEGLIGIBLE
301999992   +        19999.   NEGLIGIBLE    +   .011     +   .126    NEGLIGIBLE
            -        19999.   NEGLIGIBLE    -   .011     -   .126    NEGLIGIBLE
301999993   +     16000000.   NEGLIGIBLE    +   .050     +   .026    NEGLIGIBLE
            -     16000000.   NEGLIGIBLE    -   .050     -   .026    NEGLIGIBLE
```

Table 4-3-a. 1980 CHEMICAL MANUFACTURING EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
301002000	7083000.	NEGLIGIBLE	.243	.003	NEGLIGIBLE
301002010	6073000.	NEGLIGIBLE	.243	.003	NEGLIGIBLE
301002020	1010000.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301003000	2832500.	NEGLIGIBLE	.036	.054	NEGLIGIBLE
301003010	892000.	NEGLIGIBLE	.001	.054	NEGLIGIBLE
301003020	861500.	NEGLIGIBLE	.034	0.000	NEGLIGIBLE
301003030	643500.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301003990	435500.	NEGLIGIBLE	.000	0.000	NEGLIGIBLE
301005000	6217000.	NEGLIGIBLE	.328	2.369	NEGLIGIBLE
301005010	105960.	NEGLIGIBLE	.094	.425	NEGLIGIBLE
301005020	254010.	NEGLIGIBLE	.000	.004	NEGLIGIBLE
301005030	35795.	NEGLIGIBLE	.031	.094	NEGLIGIBLE
301005040	553100.	NEGLIGIBLE	.116	.621	NEGLIGIBLE
301005050	721600.	NEGLIGIBLE	.079	1.170	NEGLIGIBLE
301005990	4546600.	NEGLIGIBLE	.009	.055	NEGLIGIBLE
301005991	4003000.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301005992	425400.	NEGLIGIBLE	.004	.009	NEGLIGIBLE
301005993	24330.	NEGLIGIBLE	.005	.045	NEGLIGIBLE
301005994	44550.	NEGLIGIBLE	.000	.000	NEGLIGIBLE
301005995	49290.	NEGLIGIBLE	0.000	0.000	NEGLIGIBLE
301999000	151180000.	NEGLIGIBLE	.518	.336	NEGLIGIBLE
301999990	151180000.	NEGLIGIBLE	.518	.336	NEGLIGIBLE
301999991	70000000.	NEGLIGIBLE	.276	.067	NEGLIGIBLE
301999992	181500.	NEGLIGIBLE	.018	.153	NEGLIGIBLE
301999993	81000000.	NEGLIGIBLE	.224	.116	NEGLIGIBLE

Table 4-3-b. 1980 CHEMICAL MANUFACTURING UNCERTAINTIES

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980 RUN DATE=JUNE 24,1976

MODIFIED SCC		TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR)			
			NOX	HC	CO	PART
301002000	+	288470.	NEGLIGIBLE	+ .032	+ .001	NEGLIGIBLE
	-	288470.	NEGLIGIBLE	- .032	- .001	NEGLIGIBLE
301002010	+	284580.	NEGLIGIBLE	+ .032	+ .001	NEGLIGIBLE
	-	284580.	NEGLIGIBLE	- .032	- .001	NEGLIGIBLE
301002020	+	47180.	NEGLIGIBLE	+ 0.000	+ 0.000	NEGLIGIBLE
	-	47180.	NEGLIGIBLE	- 0.000	- 0.000	NEGLIGIBLE
301003000	+	68686.	NEGLIGIBLE	+ .005	+ .036	NEGLIGIBLE
	-	68666.	NEGLIGIBLE	- .005	- .036	NEGLIGIBLE
301003010	+	41862.	NEGLIGIBLE	+ .000	+ .036	NEGLIGIBLE
	-	41862.	NEGLIGIBLE	- .000	- .036	NEGLIGIBLE
301003020	+	40365.	NEGLIGIBLE	+ .005	+ 0.000	NEGLIGIBLE
	-	40365.	NEGLIGIBLE	- .005	- 0.000	NEGLIGIBLE
301003030	+	30270.	NEGLIGIBLE	+ 0.000	+ 0.000	NEGLIGIBLE
	-	30270.	NEGLIGIBLE	- 0.000	- 0.000	NEGLIGIBLE
301003990	+	20485.	NEGLIGIBLE	+ .000	+ 0.000	NEGLIGIBLE
	-	20485.	NEGLIGIBLE	- .000	- 0.000	NEGLIGIBLE
301005000	+	237320.	NEGLIGIBLE	+ .087	+ .411	NEGLIGIBLE
	-	237320.	NEGLIGIBLE	- .087	- .411	NEGLIGIBLE
301005010	+	96857.	NEGLIGIBLE	+ .086	+ .389	NEGLIGIBLE
	-	96857.	NEGLIGIBLE	- .086	- .389	NEGLIGIBLE
301005020	+	20185.	NEGLIGIBLE	+ .000	+ .000	NEGLIGIBLE
	-	20185.	NEGLIGIBLE	- .000	- .000	NEGLIGIBLE
301005030	+	3070.	NEGLIGIBLE	+ .003	+ .008	NEGLIGIBLE
	-	3070.	NEGLIGIBLE	- .003	- .008	NEGLIGIBLE
301005040	+	47482.	NEGLIGIBLE	+ .011	+ .062	NEGLIGIBLE
	-	47482.	NEGLIGIBLE	- .011	- .061	NEGLIGIBLE
301005050	+	61941.	NEGLIGIBLE	+ .008	+ .116	NEGLIGIBLE
	-	61941.	NEGLIGIBLE	- .007	- .116	NEGLIGIBLE
301005990	+	201070.	NEGLIGIBLE	+ .001	+ .005	NEGLIGIBLE
	-	201070.	NEGLIGIBLE	- .001	- .005	NEGLIGIBLE
301005991	+	200000.	NEGLIGIBLE	+ 0.000	+ 0.000	NEGLIGIBLE
	-	200000.	NEGLIGIBLE	- 0.000	- 0.000	NEGLIGIBLE

Table 4-3-b. 1980 CHEMICAL MANUFACTURING UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING            PAGE  2
      TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975      RUN DATE=JUNE 24,1976
  MODIFIED          TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX            HC             CO           PART

301005992  +        19999.       NEGLIGIBLE    +  .000       +  .001      NEGLIGIBLE
           -        19999.       NEGLIGIBLE    -  .000       -  .001      NEGLIGIBLE
301005993  +         1000.       NEGLIGIBLE    +  .001       +  .005      NEGLIGIBLE
           -         1000.       NEGLIGIBLE    -  .001       -  .005      NEGLIGIBLE
301005994  +         2000.       NEGLIGIBLE    +  .000       +  .000      NEGLIGIBLE
           -         2000.       NEGLIGIBLE    -  .000       -  .000      NEGLIGIBLE
301005995  +         4999.       NEGLIGIBLE    + 0.000       + 0.000      NEGLIGIBLE
           -         4999.       NEGLIGIBLE    - 0.000       - 0.000      NEGLIGIBLE

301999000  +     17464000.       NEGLIGIBLE    +  .065       +  .129      NEGLIGIBLE
           -     17464000.       NEGLIGIBLE    -  .065       -  .129      NEGLIGIBLE

301999990  +     17464000.       NEGLIGIBLE    +  .065       +  .129      NEGLIGIBLE
           -     17464000.       NEGLIGIBLE    -  .065       -  .129      NEGLIGIBLE

301999991  +      7000000.       NEGLIGIBLE    +  .039       +  .010      NEGLIGIBLE
           -      7000000.       NEGLIGIBLE    -  .039       -  .010      NEGLIGIBLE
301999992  +        19999.       NEGLIGIBLE    +  .011       +  .126      NEGLIGIBLE
           -        19999.       NEGLIGIBLE    -  .011       -  .126      NEGLIGIBLE
301999993  +     16000000.       NEGLIGIBLE    +  .050       +  .026      NEGLIGIBLE
           -     16000000.       NEGLIGIBLE    -  .050       -  .026      NEGLIGIBLE
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4.3 EMISSION ANALYSIS

The NEDS categorizes chemical manufacturing as a member of the industrial process family of stationary sources of emissions (Ref. 4-2). Industrial process emissions are compared to other point sources in Table 4-4. Industrial process emissions for chemical manufacturing (SCC 3-01-xxx-xx) are compared in Table 4-5 with emissions from the petroleum industry and other members of the industrial process group. The PART and NO_x emissions from chemical manufacturing represent a small fraction, approximately three percent and four percent, respectively, of total industrial process emissions. Since the PART and NO_x emissions from chemical manufacturing processes represent such small fractions of the totals from stationary sources, these pollutants were largely neglected in this study.

The charge rate, emissions, and other pertinent data were extracted from the NEDS point source data for each of the 143 SCC process categories in the chemical manufacturing group. Table 4-6 ranks the categories with the highest charge rates. Tables 4-7 and 4-8, respectively, list the most significant chemical manufacturing emitters by SCC category and product for HC and CO emissions. In comparing the process categories that produce the most emissions (Tables 4-7 and 4-8) to those having the highest charge rates (Table 4-6), it is seen that the miscellaneous synthetic rubber production (3-01-026-99) and the ammonium nitrate prilling tower cooler (3-01-027-03) categories have high charge rates, but are not producers of the largest amount of pollutants.

As a check against erroneous data, the effective emission factors from the NEDS data (emissions and charge rate) were compared with data published elsewhere. Although little data were available (data were obtained only from Refs. 4-4 and 4-5), good agreement existed where comparisons could be made. These comparisons plus a general knowledge

Table 4-4. NATIONWIDE POINT SOURCE EMISSIONS[a]

Source Category	Emissions, ~ tons/yr			
	PART	NO_x	HC	CO
Fuel Combustion	5,414,427	8,922,937	239,403	645,880
Industrial Processes	8,427,012	3,728,717	7,033,590	21,132,667
Other Point Sources	150,847	29,725	165,847	5,455,023
Total	13,992,286	12,681,379	7,438,840	27,233,570

[a] Ref. 4-3.

Table 4-5. INDUSTRIAL PROCESS EMISSIONS[a]

Source Category	PART	NO_x	HC	CO
Total Industrial Process Emissions, tons/yr				
Chemical Manufacturing: SCC 3-01-xxx-xx	232,886 (2.76%)	155,068 (4.16%)	2,319,544 (32.98%)	5,992,262 (28.36%)
Petroleum Industry: SCC 3-06-xxx-xx	1,036,281 (12.30%)	3,264,812 (87.56%)	1,012,131 (14.39%)	4,524,476 (21.41%)
Other Industrial Processes[b]	7,157,845 (84.94%)	308,837 (8.28%)	3,701,915 (52.63%)	10,615,929 (50.23%)
Total Industrial Processes	8,427,012 (100%)	3,728,717 (100%)	7,033,590 (100%)	21,132,667 (100%)
Total Nationwide Point Source Emissions, %				
Chemical Manufacturing	1.7	1.2	31.2	22.0
Petroleum Industry	7.4	25.7	13.6	16.6
Other Industrial Processes	51.2	2.4	48.8	39.0
Total Industrial Processes	60.2	29.4	94.6	77.6

[a] Ref. 4-3.

[b] Includes such processes as food, agriculture, primary metals, and secondary metals.

Table 4-6. PRODUCERS OF GREATEST EMISSIONS IN CHEMICAL MANUFACTURING

Rank	SCC	Number of Point Sources	Source Category	Annual Production Rate, tons/yr[a]
1	3-01-999-99	1944	Miscellaneous chemical manufacturing	151.29×10^6
2	3-01-026-99	189	Miscellaneous synthetic rubber production	13.63×10^6
3	3-01-021-99	40	Miscellaneous sodium carbonate production	11.67×10^6
4	3-01-018-99	225	Miscellaneous plastics production	5.30×10^6
5	3-01-005-99	74	Miscellaneous carbon black production	4.75×10^6
6	3-01-002-01	33	Ammonia production with methanator	4.62×10^6
7[b]	3-01-027-03	41	Ammonium nitrate with prilling tower	4.25×10^6

[a] Also known as annual charge rate (ACR).

[b] These categories were not among the five categories yielding the greatest emissions in the chemical manufacturing group.

Table 4-7. PRODUCERS OF GREATEST HC EMISSIONS IN CHEMICAL MANUFACTURING

Rank by Emissions

Rank	SCC	Source Category	Effective Emission Factor, lb/ton[a]	Emission Rate, tons/yr
1	3-01-999-99	Miscellaneous chemical manufacturing	6.86	519×10^3
2	3-01-005-01	Carbon black, channel	1767.	227×10^3
3	3-01-002-01	Ammonia with methanator	69.2	160×10^3
4	3-01-005-04	Carbon black, furnace oil	425.	82×10^3
5	3-01-018-99	Miscellaneous plastics production	30.6	81×10^3

Rank by Product

Rank	Product	Production Rate		Emission Rate	
		Tons/yr	%	Tons/yr	%
1	Carbon black	0.634×10^6	0.4	309×10^3	29
2	Ammonia	4.622×10^6	2.9	160×10^3	15
3	Plastics	5.296×10^6	3.3	81×10^3	8
4	Other	151.3×10^6	93.5	519×10^3	49
	Total	161.85×10^6	100	1069×10^3	100

[a] Effective emission factor is the emission rate (lb/yr) divided by the production rate (tons/yr).

Table 4-8. PRODUCERS OF GREATEST CO EMISSIONS IN CHEMICAL MANUFACTURING

Rank by Emissions

Rank	SCC	Source Category	Effective Emission Factor, lb/ton[a]	Emission Rate, tons/yr
1	3-01-005-01	Carbon black, channel	8031.	1032×10^3
2	3-01-005-05	Carbon black, furnace oil and gas	3246.	797×10^3
3	3-01-005-04	Carbon black, furnace oil	2137.	403×10^3
4	3-01-999-99	Miscellaneous chemical	4.44	336×10^3
5	3-01-005-03	Carbon black, furnace gas	5000.	60×10^3
6	3-01-005-99	Carbon black, miscellaneous processes	24.44	58×10^3

Rank by Product

Rank	Product	Production Rate		Emission Rate	
		Tons/yr	%	Tons/yr	%
1	Carbon black	5.90×10^6	3.8	2350×10^3	87
2	Miscellaneous chemical manufacturing	151.29×10^6	96.2	336×10^3	13
	Total	157.19×10^6	100	2686×10^3	100

[a] Effective emission factor is the emission rate (lb/yr) divided by the production rate (tons/yr).

of the subject process resulted in the elimination of synthetic rubber and ammonium nitrate manufacturing as major contributors of the four emissions of interest.

4.3.1 Chemical Manufacturing Processes Studied

As mentioned, only unburned HC and CO emissions were examined when forming the list of products and SCCs for which future charge rate and emission forecasts were to be made. All SCC categories related to an offending product were studied regardless of the magnitude of the current emissions represented by any one SCC. Table 4-7 shows that certain carbon black, ammonia, and miscellaneous chemical manufacturing emissions represent 93 percent of the HC emitted by the five largest producers in the chemical manufacturing category. Table 4-8 shows that certain carbon black manufacturing processes produce the most CO emissions in the chemical manufacturing group.

The chemical manufacturing products and SCC categories for which future emissions and production rates were projected are as follows:

SCC	Product
3-01-0002-xx	Ammonia made with methanator
3-01-003-xx	Ammonia made with CO absorber
3-01-005-xx	Carbon black
3-01-999-99	Miscellaneous chemical manufacturing

These four broad categories were divided into 19 MSCC categories, and a current data base and 1980 projection were made for each. More detailed definitions of these processes, as well as charge rates, are listed in Table 4-1.

4.3.2 General Observations

In the course of the chemical manufacturing emissions study, certain errors and discrepancies were noted in the NEDS point source emission data. Most of these observations were trivial, but two were believed sufficiently significant to be reported here.

4.3.2.1 Summary of Point Source Comparison

The charge rate (production) and emissions as extracted from the NEDS point source data (Ref. 4-6) are shown in Table 4-9 for the chemical manufacturing group. Although the years of record vary from 1969 to 1973 for the NEDS data, the preponderance of SCC data is for 1971. The emissions from Refs. 4-3, 4-6, and 4-7 are summarized in the following table and are presented graphically in Figure 4-1.

Data Source	Emissions, million tons/yr			
	PART	NO_x	HC	CO
NEDS Tape:				
1971	0.28	0.33	1.42	2.92
NEDS Nationwide Emission Summary Report:				
December 1973	0.22	0.15	2.37	6.01
January 1975	0.23	0.16	2.33	5.99

A discontinuity appears to exist between the 1971 and the 1974-75 data shown in Figure 4-1, indicating an inconsistency in ground rules or methods of establishing the two sets of data. Two known factors which may have contributed to the inconsistency are listed here. Their exact effects are unknown, but are believed to be significant.

a. Emissions listed on the NEDS tape are based frequently on preliminary (sometimes inaccurate) emission factors (Ref. 4-4) or in some cases simply a guess. A comparison of emission factors published in Refs. 4-4 and 4-5 reflects the size of certain data errors. These could cause either high or low emissions to be entered on the NEDS tape.

Table 4-9. SUMMARY OF CHEMICAL MANUFACTURING AND EMISSIONS REPORTED IN NEDS[a]

SCC	Annual Charge Rate[b]	Emissions, ~ tons/yr			
		PART	NO_x	HC	CO
3-01-002-01	4,621,676	118	3,259	160,008	2,777
3-01-002-02	766,500	-	-	-	-
3-01-002-99	-	-	-	-	-
3-01-002		118 (-%)	3,259 (1.0%)	160,008 (11.3%)	2,777 (0.1%)
3-01-003-01	679,793	40	65	772	10,995
3-01-003-02	651,996	119	-	2,510	-
3-01-003-03	486,877	-	-	-	-
3-01-003-99	330,000	-	-	331	-
3-01-003		159 (0.1%)	65 (-%)	3,613 (0.3%)	10,995 (0.4%)
3-01-005-01	257,163	22,146	-	227,337	1,031,710
3-01-005-02		-	-	-	-
3-01-005-03	24,381	3,614	-	19,997	63,469
3-01-005-04	376,731	901	435	82,204	402,659
3-01-005-05	491,484	7,168	10	54,013	797,087
3-01-005-99	4,745,552	8,079	68	8,967	57,506
3-01-005		41,908 (15.2%)	513 (0.2%)	392,518 (27.7%)	2,352,431 (80.7%)
3-01-999-99	151,288,357	69,015 (25.0%)	44,054 (13.3%)	518,506 (36.5%)	335,500 (11.5%)
3-01-008	248,813 (100 tons/yr)	343 (0.1%)	55,730 (16.8%)	- (-)	144 (-%)
3-01-033-01	3,000 (gal/yr)	- (-)	- (-)	5,801 (0.4%)	- (-)
3-01-900-99	747 (million cu ft/yr)	4,667 (1.7%)	146 (-)	- (-)	18,850 (0.6%)
Other 3-01	182,696,930	159,870 (57.9%)	228,523 (68.8%)	338,554 (23.9%)	194,503 (6.7%)
Total		276,080 (100%)	332,290 (100%)	1,419,000 (100%)	2,915,200 (100%)

[a] Extracted from Ref. 4-6.

[b] Unless otherwise specified, charge rate units are in tons of product per year.

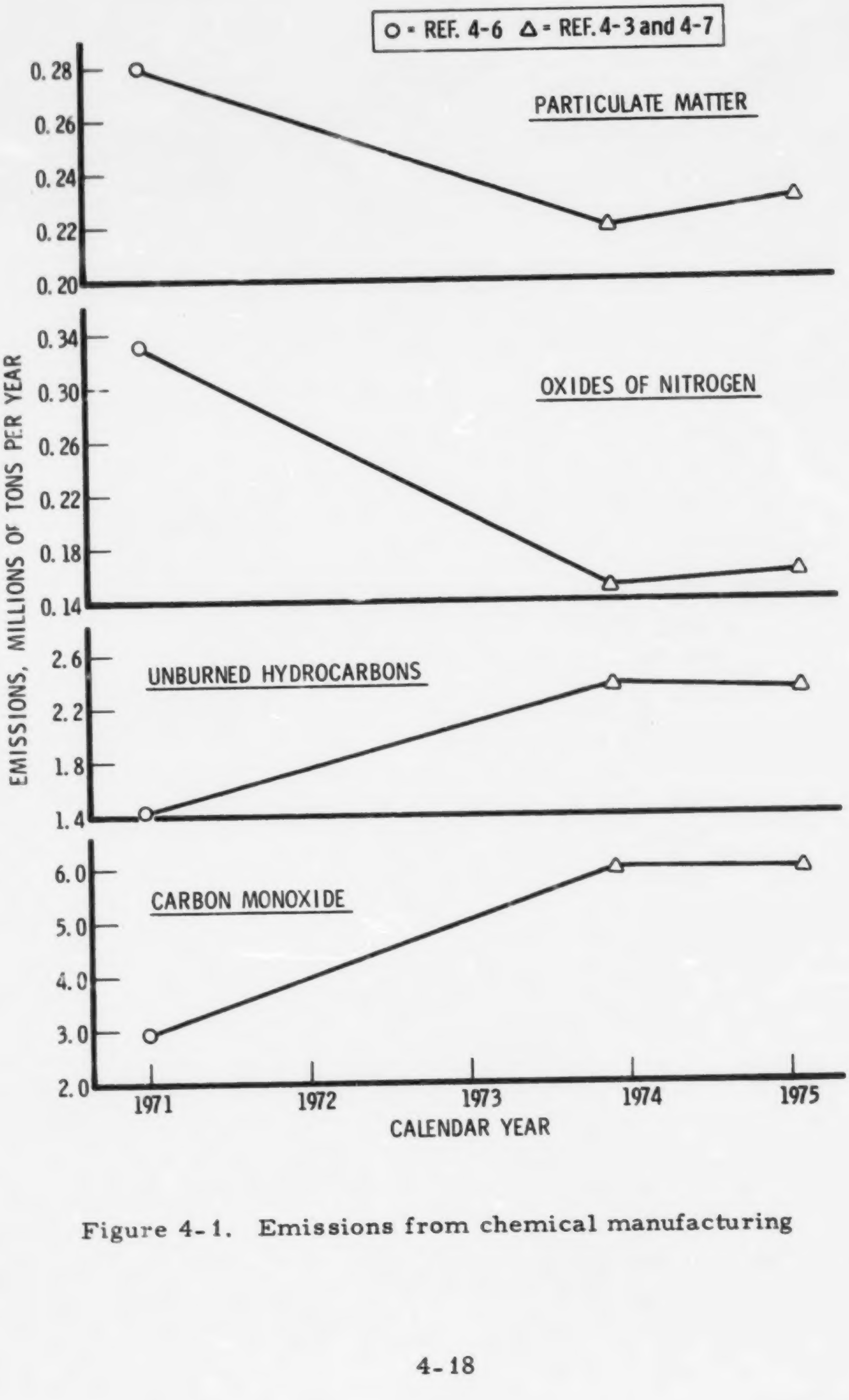

Figure 4-1. Emissions from chemical manufacturing

b. Emissions listed in the summary reports (Refs. 4-3 and 4-7) are based on the product of charge rate and known emission factors. Where the emission factors are not known, zero emissions are entered. This characteristic can only cause the summary report emissions to be low.

4.3.2.2 Lack of Thermal Carbon Black Data

No data were reported under SCC 3-01-005-002 thermal carbon black production. Reference 4-8 shows a steady growth from 47,000 tons in 1950 to 137,000 tons in 1965. Approximately 170,000 tons should have been reported in 1970 according to the trend reported in Ref. 4-8. Total carbon black production in 1970 as extracted from the NEDS falls on the trend line established from Ref. 4-8 only if some production other than that reported in the SCC categories 3-01-005-01, -03, -04, and -05 existed. The difference is close to the forecast production of thermal black in the Ref. 4-8 data. Either thermal carbon black was not reported or it was erroneously reported in SCC 3-01-005-99. Normally, this SCC would be used to report carbon black handling or the manufacturing of some product where carbon black is a principal ingredient. That portion of SCC 3-01-005-99 corresponding to SIC 2895 is close to the deficit. Of the nine SICs comprising SCC 3-01-005-99, SIC 2895 is the only one identified as carbon black.

4.3.3 Ammonia Production

4.3.3.1 Process Description

Two principal methods of ammonia (NH_3) production exist:

a. Methanator process

b. CO absorber process

Both processes combine nitrogen (N) from the atmosphere with hydrogen (H_2) from some HC feed stock such as natural gas. The difference in the two techniques is centered on how the large amounts of CO are handled. The CO results when H_2 is extracted from the HC feed stock. While the CO emissions in the main process of ammonia production are substantially less in the CO absorber technique, the CO efflux from the absorber when it is being rejuvenated tends to be quite high. An extensive water scrubber and incinerator system can considerably reduce the CO emissions during absorber regeneration.

Unburned HC emissions (usually methane) from the purge gas stream are of the same concentration whether the methanator or CO absorber system is used. Scrubbers have a modest effect on HC emissions.

Although beyond the scope of this study, another noteworthy emission is ammonia vapor. This emission can be reduced to almost any level of insignificance through repeated water scrubber application.

4.3.3.2 Data Research and Analysis

Production rates* of synthetic ammonia are recorded in Refs. 4-6 and 4-9. The charge rate history is graphically presented in Figure 4-2. Several straight lines were derived by least square fit techniques from various combinations of the data points on Figure 4-2. The straight line obtained when 1964 and 1965 data were excluded yielded the best correlation. Its equation was used when estimating future ammonia production. The uncertainty in baseline production is simply the standard error of estimate obtained with the straight line derivation. The uncertainty of the production slope is the difference in slope for the adopted line and the line derived using the six data points in Figure 4-2. This number is approximately 21 percent of the baseline value.

The total production reflected in Figure 4-2 is considered to be apportioned among the six SCC categories for all years in the same percentage as that listed by the NEDS for the 1970-72 era. Emission factor data are found in three areas:

---

*The term "production rate" as used here refers to the charge rate associated with the particular operation; e.g., SCC 3-01-002-02 is related to storage and loading, and the ammonia charge rate was actually produced or created under 3-01-002-01 for methanator systems. The production SCC for CO absorption systems is 3-01-003-02.

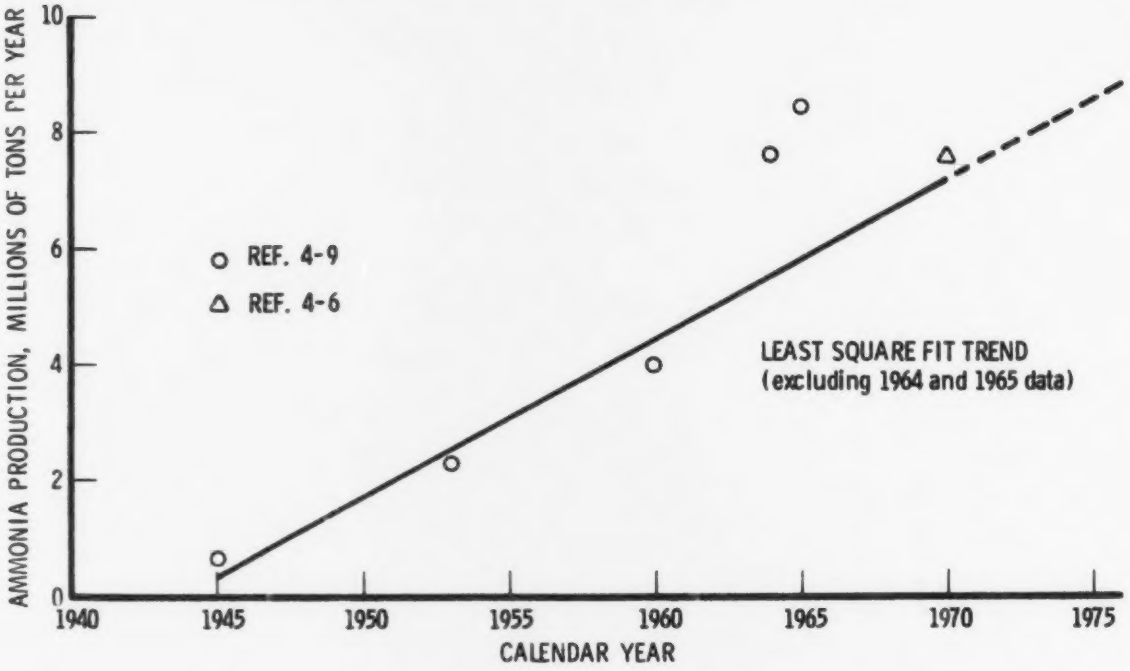

Figure 4-2. Synthetic ammonia production

a. Reference 4-5

b. Reference 4-10

c. Quotient of emissions and charge rate from Ref. 4-6 data.

Where emission factor data exist in Ref. 4-10, they are considered to supersede Ref. 4-5 data. In the following discussion, that which prevails between Refs. 4-5 and 4-10 will be referred to as the "EPA emission factor."

Where reasonable agreement (i.e., less than 15 percent difference) exists between the EPA emission factor and that derived from the NEDS data, the average of the two was established as the baseline value. Where the difference was great, a third source was enlisted as a referee; where no third source was available, engineering judgment was exercised on the basis of knowledge of the process in question. The uncertainty in the baseline emission factor is simply the difference between the baseline value and the nearest source value which contributed to its derivation.

As mentioned, PART and NO_x emissions from chemical manufacturing were so small (Table 4-5) in comparison to the total industrial process that no time was spent in establishing their emission factors (or related variables like slope or uncertainties); these emissions were defined as negligible for all future years.

The literature survey described ammonia production processes as having remained essentially unchanged since 1953, and no substantial changes in controls or process are forecast for the immediate future. As a result, the slope and the slope uncertainties for ammonia emission factors were set to zero.

4.3.3.3 Projections of Ammonia Activity

The total HC emission from ammonia production in 1980 is estimated to be 279,000 tons ± 32,000. The majority (243,000 tons) of these emissions is from methanator-type production. The total estimated CO emissions from ammonia industries in 1980 is 57,000 tons ± 36,000. The NO_x and PART emissions are expected to be negligible in 1980 (as is the case presently) compared to other point source industrial processes emissions.

4.3.4 Carbon Black Industry

4.3.4.1 Processes and Uses

Carbon black is an oil-free ultrafine soot. Although it is used in the paint and printing industry as a pigment, the prominent use is in the rubber industry as a reinforcing agent. Tires, for example, roll three to five times farther with carbon black than without.

Three principal techniques of carbon black production exist:

a. Impingement process
b. Thermal process
c. Furnace process

The furnace process, which accounts for most carbon black production, is subdivided further according to fuel type: oil, natural gas, and oil-enriched natural gas.

The impingement and thermal processes involve incomplete combustion of HC fuel, whereas the thermal process involves thermal decomposition (or cracking) of natural gas by exposing it to heated (2400° to 2800°F) brick work. The impingement process (also called channel process) involves natural gas-fueled flames impinging on surfaces of steel (usually channel cross section) and depositing carbon black. The carbon black is periodically scraped off the channels before pelletizing (to increase the density for more economical shipment) for packaging and shipment. Channel black is one of the finest (20 to 50 nm particle size) grades made. Furnace black particle size is 25 to 160 nm. Although the thermal process produces a much larger particle size (150 to 500 nm) and consequently facilitates control of particulate-type HC emissions, many users of carbon black, such as tire manufacturers, simply cannot use this product. The furnace process employs refractory-lined furnace combustion chambers where the natural gas and oil is burned with insufficient air. The process is continuous in nature, whereas the thermal and impingement processes are cyclic. Furnace reactors have grown to be sophisticated efficient plants compared to the channel black burner houses. The latter are normally temporarily set up at the source of cheap natural gas and involve few controls (except for air flow). Gas furnaces yield 12 to 16 lb of carbon black per 1000 cu ft of gas compared to a yield of 2 to 3 lb/1000 cu ft from the channel black process. The theoretical yield is approximately 32 lb/ 1000 cu ft.

By its nature, carbon black production is a high emitter of HC and CO. Although much of the following practice was implemented to improve efficiency, pollution control benefits are inherent. Since most HC emission are in the form of soot particulate, the most common forms of alleviation are cyclone separators; water scrubbers; bag filters; and, more recently, electrostatic percipitators. Also some consideration has been given to burning HC emissions. This would alleviate the flow of gaseous emissions such as methane as well as the fine particulate soot. CO emissions are left essentially uncontrolled in carbon black production.

4.3.4.2 Data Research and Analysis

4.3.4.2.1 Carbon Black Production

Production rates of carbon black are listed in Ref. 4-8 for selected years from 1925 to 1965. Production rates for 1970 are recorded in Ref. 4-6. With some difficulty, the data from Ref. 4-8 for the years 1950, 1955, 1960, and 1965 were merged with the Ref. 4-6 data to establish a modern-day trend. Two problems were encountered:

a. The Ref. 4-8 furnace data were not broken down by type, i.e., oil, gas, or oil and gas.

b. No production rates were recorded in Ref. 4-6 for thermal black.

Problem a. was disposed of by assuming Ref. 4-8 furnace charge rates were apportioned among the three processes on a percentage basis the same as the Ref. 4-6 data.

The trend of total carbon black production for 1970 follows the same curve as Ref. 4-8 data only if some carbon black production exists other than that reported in Ref. 4-6 under the SCC categories 3-01-005-01, -03, -04, and -05. As seen in Figure 4-3, the deficit closely matches the charge rate reported under SIC 2895 of SCC 3-01-005-99. These observations (plus the fact that corporations listed in the NEDS point source data were involved in other carbon black production) led to defining the 1970 production as the sum of the charge rate for the four previously mentioned SCC categories and the portion of SCC 3-01-005-99 allocated to SIC 2895. Products corresponding to SIC classifications are defined in Ref. 4-1. Figure 4-4 shows the production rate of carbon black for the five processes under these ground rules.

Trend curves were established for the production rate of each process by deriving the least square fit straight line using various combinations of the 1955 to 1970 data. Figure 4-4 shows the curve which used all five sets of data between 1950 and 1970. Even though the 1950-65 data resulted in a better fit (higher correlation coefficient), it was decided to use (for future black production estimates) those curves derived from all five points (1950 to 1970). The rationale was as follows:

a. The inclusion of the latest data (1970) adds credence to future estimates.

b. Use of data from several sources offsets errors in individual data where checking for validity is not possible.

These trend curves were used to establish baseline production in the year 1975. The uncertainty in baseline production is equal to the standard error of estimate obtained in deriving the straight line. The uncertainty of the baseline slope (change in production rate per year) was defined as the difference in slope of straight lines using all five points and that excluding the 1970 data.

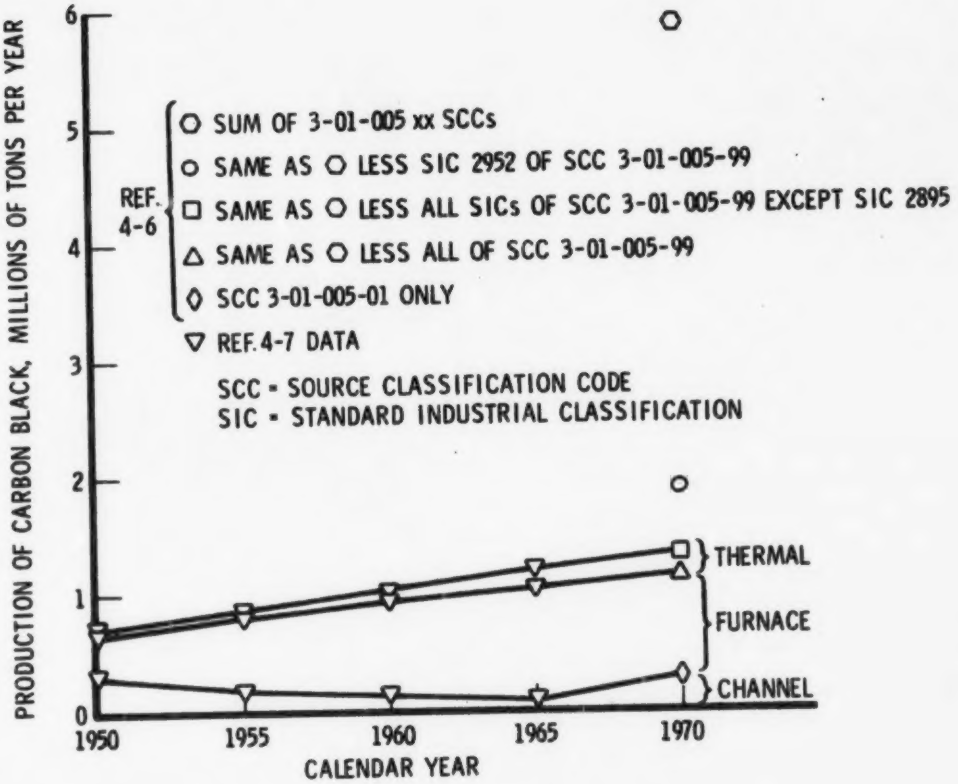

Figure 4-3. Total carbon black production

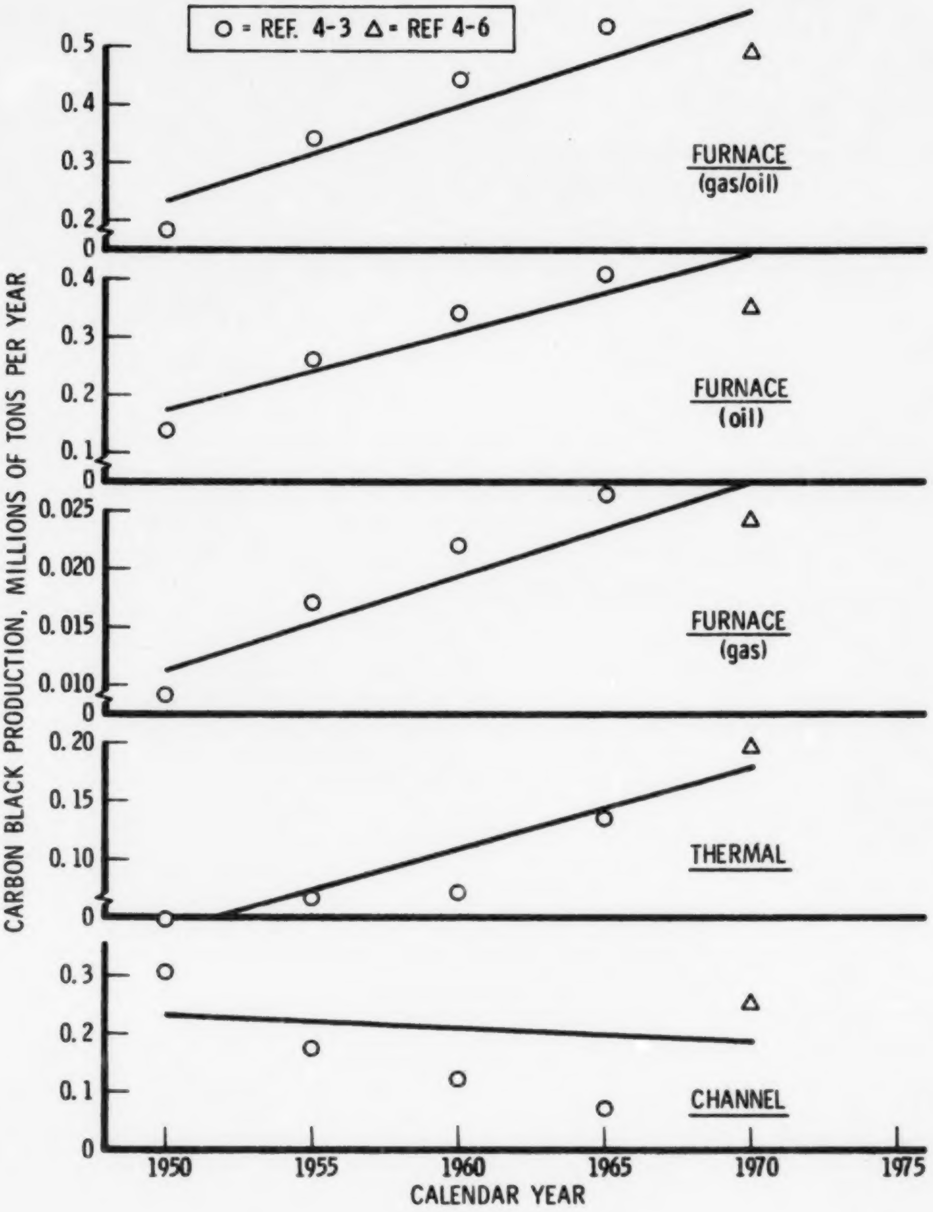

Figure 4-4. Breakdown of carbon black production

Emission factors for carbon black production are reported in Refs. 4-5 and 4-10 and also can be calculated by dividing the pounds of emissions by the tons of carbon black produced from Ref. 4-6. Data in Ref. 4-10 for a particular process were considered an update of Ref. 4-5 data. Reference 4-5 or 4-10 data (whichever prevail) is referred to as the "EPA emission factor." The other source is called the "NEDS emission factor." Where reasonable agreement (i.e., ≤ 15 percent difference) exists between the EPA and NEDS emission factors, the average of the two values was established as baseline and its uncertainty was the difference between the baseline value and the parent data.

Three cases were encountered where the EPA emission factor differed substantially from the one based on the NEDS data:

a. Hydrocarbon emission factor for channel process

b. Carbon monoxide emission factor for channel process

c. Carbon monoxide emission factor for oil-fed furnace.

It was reasoned that the emission factors should be inversely proportional to the percent theoretical product yield.

The theoretical maximum yield of carbon black is 32 lb/1000 cu ft of natural gas. However, according to Ref. 4-11, approximately 40 percent of this HC is needed to raise the temperature sufficiently to separate the carbon. Therefore, if none of the 32 lb of carbon black were collected, approximately 19 lb would escape to the atmosphere, and the remainder would be consumed to heat the gas. Stated mathematically, the hypothesis is as follows:

$$\frac{EF_1}{EF_2} = \frac{(1.0 - 0.4 - \eta_1)\,\eta_2}{(1.0 - 0.4 - \eta_2)\,\eta_1}$$

where

EF = emission factor

η = decimal fraction of 32 lb that the process yields of carbon black

Since the emission factor for furnace process with gas was known (i.e., good agreement between the EPA emission factor and the one derived from the NEDS), it was used as a basis to establish the three discrepant emission factors. This approach yielded values so close to the ones derived from the NEDS data that the latter was selected for channel baseline emission factors.

In the case of the oil-fired furnace process, the baseline CO emission factor was defined as five percent higher than the one based on NEDS data.

4.3.4.2.2 Miscellaneous Carbon Black Processes

Data were prepared to allow projections to be made in the five MSCC categories of the miscellaneous carbon black industry (MSCC 3-01-005-99). These MSCC categories were based on the SIC classifications listed below and their corresponding products and comprised the point sources under SCC 3-01-005-99 in Ref. 4-6 of the NEDS data:

MSCC	SIC	Product
3-01-005-99-1	2952	Asphalt, felts, and coatings
3-01-005-99-2	3624	Carbon and graphite products
3-01-005-99-3	3999	Manufacturing industries NEC[a]
3-01-005-99-4	2899	Chemical preparation NEC
3-01-005-99-5	3334 3069 3991 2999	Primary aluminum Fabricated rubber products Brooms and brushes Petroleum and coal products

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[a] Not elsewhere classified (NEC).

The baseline charge rate was set equal to the NEDS (1970) value. Uncertainties were set at 5 percent of the base value for categories MSCC 3-01-005-99-1 through 3-01-005-99-4 and to 10 percent for MSCC 3-01-005-99-5, which is a bigger uncertainty since it is comprised of a broad collection of activities. Typical uncertainty of the carbon black production is eight percent.

The baseline emission factors were set equal to the NEDS emissions divided by the charge rate. The emission factor uncertainty was set to 10 percent of baseline value, which was typical of the primary carbon black production SCC categories.

Since little is known about the production and processes in this miscellaneous manufacturing group, no attempt was made to establish a finite slope (trend) or slope uncertainty of any of the data leading to projections of the 3-01-005-99 SCC categories.

4.3.4.3 Projections of Carbon Black Activity

The estimated HC emissions in 1980 carbon black industries are 328,000 tons ± 87,000. Although the channel process is by far the dirtiest (high emission factor), its HC emissions are down both trend-wise and process-wise. The 1980 channel black production is 94,000 tons compared to 116,000 for the oil-fired furnace process. The estimated channel black HC emissions in 1975 are 112,000 tons.

The estimated CO emissions from carbon black in 1980 are 2.37-million tons ± 411,000 tons. The oil-enriched natural gas-fired furnace technique leads CO emissions with 1.17-million tons in 1980.

4.3.5 Miscellaneous Chemical Manufacturing

4.3.5.1 Products

Some 78 separate products (SIC classifications) at 1944 point sources comprised the miscellaneous chemical manufacturing (SCC 3-01-999-99) categories in the NEDS data tape. Entries made under

SIC 2818 and 3999, respectively, constituted approximately 50 percent of the HC and CO emissions. The 76 other SIC products combined represented only 43 percent of the HC and 35 percent CO emissions. Emission projections were made for three subdivisions of miscellaneous chemical manufacturing: (1) SIC 2818, (2) SIC 3999, and (3) remainder (other than SIC 2818 and 3999). SIC 2818 was not defined in Ref. 4-1, but such a classification would be a member of the industrial inorganic chemicals under SIC 281x.

SIC 3999 designates manufacturing industries NEC.

4.3.5.2 Data Definition

The baseline charge rates and emission factors for each category were set equal to the value calculated from the NEDS data (Ref. 4-6). The uncertainties in charge rates and emission factors were based on other chemical manufacturing (ammonia and carbon black).

Slopes and slope uncertainties were set to zero since little is known about the collage of industrial activity.

4.3.5.3 Projections of Miscellaneous Chemical Manufacturing

The estimated 1980 HC and CO emissions from miscellaneous chemical manufacturing are 518,000 ± 65,000 tons and 336,000 ± 129,000 tons, respectively.

4.4 REFERENCES

4-1. Standard Industrial Classification Manual, Executive Branch of The Federal, Government, Statistical Policy Division, Washington, D.C. (1972).

4-2. Guide for Compiling a Comprehensive Emission Inventory, Revised, APTD-1135, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (March 1973).

4-3. NEDS Nationwide Emissions Report as of January 10, 1975 (with New York and West Virginia Supplement), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 12, 1975).

4-4. Compilation of Air Pollutant Emission Factors, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 1972).

4-5. Compilation of Air Pollutant Emission Factors, 2nd ed., AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

4-6. "Industrial Processes, Chemical Manufacturing Category," NEDS Data, The Aerospace Corporation Tape Analysis, The Aerospace Corporation, El Segundo, California (February 25, 1975).

4-7. NEDS Nationwide Emissions Report as of December 10, 1973, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (January 12, 1974).

4-8. I. Drogin, "Carbon Black," Journal of Air Pollution Control Association, Informative Report No. 9, 8 (4) (April 1968).

4-9. R. Shreve, Chemical Process Industries, 3rd ed., McGraw Hill Book Co., Inc., New York (1967).

4-10. NEDS Source Classification Codes and Emission Factor Listing (SCC Listing), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (July 1974).

4-11. T. Cox, Jr., "High Quality-High Yield Carbon Black," Chemical Engineering Journal (June 1950).

SECTION 5

PETROLEUM REFINERIES

5.1 INTRODUCTION

This section develops data for the petroleum refining industry, in terms of several important source classification codes (SCC), for emissions of particulate (PART) matter, nitrogen oxides (NO_x), unburned hydrocarbons (HC), and carbon monoxide (CO).

The purpose is to provide a general overview of the petroleum refining industry, assess the importance of specific major process sources of atmospheric emissions, estimate current and projected levels, provide the rationale used in making the projections, and present the data sources. Table 5-1 describes the process and charge rate units for each SCC studied.

5.2 SUMMARY

Petroleum industry annual charge rates and emissions were established for 1975 and estimated for 1980. These data are reported in Tables 5-2-a and 5-3-a, respectively. Uncertainty data are listed in Tables 5-2-b and 5-3-b for 1975 and 1980, respectively.

5.3 APPROACH

Developing and forecasting emission inventories requires knowledge or judgment about a combination of factors. Technological generalities are discussed in Appendix 5-A. Two important elements are total annual charge rates and emission factors. Judgments have been made about expected changes in these parameters resulting from technology advancements,

(Continued on page 5-9)

Table 5-1. DEFINITION OF PETROLEUM INDUSTRY PROCESSES

MSCC	Source Category	Charge Rate Unit
306001010	Process heater (oil-fired, major quantities)	1000 bbl burned/yr
306001020	Process heater (gas-fired, minor quantities)	1000 cu ft burned/yr
306001030	Process heater (oil-fired, minor quantities)	1000 gal burned/yr
306001040	Process heater (gas-fired, major quantities)	Million cu ft burned/yr
306002010	Fluid catalytic cracking	1000 bbl fresh feed/yr
306003010	Moving bed catalytic cracking	
306008010	Miscellaneous leakage (pipe, valve, flange)	1000 bbl refined/yr
306008020	Miscellaneous leakage (vessel relief valves)	1000 bbl refined/yr
306008030	Miscellaneous leakage (pump seals)	1000 bbl refined/yr
306008040	Miscellaneous leakage (compressor seals)	1000 bbl refined/yr
306008050	Miscellaneous leakage (other, general)	1000 bbl refined/yr
306012010	Fluid coking	1000 bbl fresh feed/yr

Table 5-2-a. 1975 PETROLEUM INDUSTRY EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, PETROLEUM INDUSTRY PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1975 RUN DATE=JUNE 24,1976

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
306001000		.507	.045	.034	.095
306001010	160600.	.233	.011	.014	.067
306001020	2200000000.	.254	.033	.019	.022
306001030	586700.	.020	.001	.001	.006
306001040	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
306002000	1500000.	.050	.170	16.800	.180
306002010	1500000.	.050	.170	16.800	.180
306003000	108500.	NEGLIGIBLE	.005	.210	NEGLIGIBLE
306003010	106500.	NEGLIGIBLE	.005	.210	NEGLIGIBLE
306008000	26250000.	NEGLIGIBLE	.187	NEGLIGIBLE	NEGLIGIBLE
306008010	5250000.	NEGLIGIBLE	.074	NEGLIGIBLE	NEGLIGIBLE
306008020	5250000.	NEGLIGIBLE	.029	NEGLIGIBLE	NEGLIGIBLE
306008030	5250000.	NEGLIGIBLE	.045	NEGLIGIBLE	NEGLIGIBLE
306008040	5250000.	NEGLIGIBLE	.013	NEGLIGIBLE	NEGLIGIBLE
306008050	5250000.	NEGLIGIBLE	.026	NEGLIGIBLE	NEGLIGIBLE
306012000	110000.	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	.027
306012010	110000.	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE	.027

Table 5-2-b. 1975 PETROLEUM INDUSTRY UNCERTAINTIES

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                    INDUSTRIAL PROCESS, PETROLEUM INDUSTRY              PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975        RUN DATE=JUNE 24,1976
                                         EMISSIONS (MILLIONS OF TONS / YEAR)
 MODIFIED          TACRP                                  HC             CO              PART
   SCC          (SCC UNITS)           NOX
                                    +  .025          +  .006         +  .005          +  .005
306001000                           -  .025          -  .006         -  .005          -  .005

306001010       +       8000.       +  .016          +  .006         +  .003          +  .005
                -       8000.       -  .016          -  .006         -  .003          -  .005
306001020       +  110000000.       +  .018          +  .002         +  .004          +  .002
                -  110000000.       -  .018          -  .002         -  .004          -  .002
306001030       +      29000.       +  .007          +  .000         +  .000          +  .002
                -      29000.       -  .007          -  .000         -  .000          -  .002
306001040          NEGLIGIBLE        NEGLIGIBLE       NEGLIGIBLE      NEGLIGIBLE       NEGLIGIBLE
                   NEGLIGIBLE        NEGLIGIBLE       NEGLIGIBLE      NEGLIGIBLE       NEGLIGIBLE

306002000       +      30000.       +  .003          +  .009         + 5.890          +  .010
                -      30000.       -  .003          -  .009         - 5.890          -  .010

306002010       +      30000.       +  .003          +  .009         + 5.890          +  .010
                -      30000.       -  .003          -  .009         - 5.890          -  .010

306003000       +       2169.        NEGLIGIBLE      +  .000         +  .011           NEGLIGIBLE
                -       2169.        NEGLIGIBLE      -  .000         -  .011           NEGLIGIBLE

306003010       +       2169.        NEGLIGIBLE      +  .000         +  .011           NEGLIGIBLE
                -       2169.        NEGLIGIBLE      -  .000         -  .011           NEGLIGIBLE

306008000       +     234790.        NEGLIGIBLE      +  .034          NEGLIGIBLE       NEGLIGIBLE
                -     234790.        NEGLIGIBLE      -  .034          NEGLIGIBLE       NEGLIGIBLE

306008010       +     105000.        NEGLIGIBLE      +  .026          NEGLIGIBLE       NEGLIGIBLE
                -     105000.        NEGLIGIBLE      -  .026          NEGLIGIBLE       NEGLIGIBLE
306008020       +     105000.        NEGLIGIBLE      +  .010          NEGLIGIBLE       NEGLIGIBLE
                -     105000.        NEGLIGIBLE      -  .010          NEGLIGIBLE       NEGLIGIBLE
306008030       +     105000.        NEGLIGIBLE      +  .016          NEGLIGIBLE       NEGLIGIBLE
                -     105000.        NEGLIGIBLE      -  .016          NEGLIGIBLE       NEGLIGIBLE
306008040       +     105000.        NEGLIGIBLE      +  .005          NEGLIGIBLE       NEGLIGIBLE
                -     105000.        NEGLIGIBLE      -  .005          NEGLIGIBLE       NEGLIGIBLE
306008050       +     105000.        NEGLIGIBLE      +  .009          NEGLIGIBLE       NEGLIGIBLE
                -     105000.        NEGLIGIBLE      -  .009          NEGLIGIBLE       NEGLIGIBLE
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Table 5-2-b. 1975 PETROLEUM INDUSTRY UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, PETROLEUM INDUSTRY              PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1975       RUN DATE=JUNE 24,1976
 MODIFIED            TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)          NOX             HC              CO           PART

306012000    +         2199.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     +   .002
             -         2199.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     -   .002

306012010    +         2199.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     +   .002
             -         2199.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     -   .002
```

Table 5-3-a. 1980 PETROLEUM INDUSTRY EMISSIONS AND CHARGE RATES

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                       INDUSTRIAL PROCESS, PETROLEUM INDUSTRY              PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1980     RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX           HC            CO           PART

306001000                           .326          .055          .038          .082

306001010           112410.         .082          .008          .010          .047
306001020        3100000000.        .234          .047          .027          .031
306001030            586700.        .010          .001          .001          .004
306001040        NEGLIGIBLE      NEGLIGIBLE    NEGLIGIBLE    NEGLIGIBLE    NEGLIGIBLE

306002000           1690000.        .056          .180        11.441          .128

306002010           1690000.        .056          .180        11.441          .128

306003000             70000.     NEGLIGIBLE       .003          .130       NEGLIGIBLE

306003010             70000.     NEGLIGIBLE       .003          .130       NEGLIGIBLE

306008000          29850000.     NEGLIGIBLE       .215       NEGLIGIBLE    NEGLIGIBLE

306008010           6150000.     NEGLIGIBLE       .087       NEGLIGIBLE    NEGLIGIBLE
306008020           6150000.     NEGLIGIBLE       .033       NEGLIGIBLE    NEGLIGIBLE
306008030           6150000.     NEGLIGIBLE       .052       NEGLIGIBLE    NEGLIGIBLE
306008040           5250000.     NEGLIGIBLE       .013       NEGLIGIBLE    NEGLIGIBLE
306008050           6150000.     NEGLIGIBLE       .030       NEGLIGIBLE    NEGLIGIBLE

306012000            120000.     NEGLIGIBLE    NEGLIGIBLE    NEGLIGIBLE       .029

306012010            120000.     NEGLIGIBLE    NEGLIGIBLE    NEGLIGIBLE       .029
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Table 5-3-b. 1980 PETROLEUM INDUSTRY UNCERTAINTIES

```
                 INDUSTRIAL PROCESS, PETROLEUM INDUSTRY                 PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980      RUN DATE=JUNE 24,1976
 MODIFIED         TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX             HC              CO              PART
306001000                       + .032          + .006          + .006          + .006
                                - .032          - .007          - .006          - .006

306001010    +      11243.      + .012          + .004          + .002          + .005
             -      11243.      - .012          - .004          - .002          - .005
306001020    +  310160000.      + .030          + .005          + .006          + .003
             -  310160000.      - .030          - .005          - .006          - .003
306001030    +      58668.      + .007          + .000          + .000          + .001
             -      58668.      - .007          - .000          - .000          - .001
306001040       NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE
                NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE      NEGLIGIBLE

306002000    +     168980.      + .006          + .020          + 6.723         + .014
             -     168980.      - .006          - .020          - 6.723         - .014

306002010    +     168980.      + .006          + .020          + 6.723         + .014
             -     168980.      - .006          - .020          - 6.723         - .014

306003000    +      21002.      NEGLIGIBLE      + .001          + .040          NEGLIGIBLE
             -      21002.      NEGLIGIBLE      - .001          - .040          NEGLIGIBLE

306003010    +      21002.      NEGLIGIBLE      + .001          + .040          NEGLIGIBLE
             -      21002.      NEGLIGIBLE      - .001          - .040          NEGLIGIBLE

306008000    +    1375200.      NEGLIGIBLE      + .041          NEGLIGIBLE      NEGLIGIBLE
             -    1375200.      NEGLIGIBLE      - .041          NEGLIGIBLE      NEGLIGIBLE

306008010    +     615030.      NEGLIGIBLE      + .031          NEGLIGIBLE      NEGLIGIBLE
             -     615030.      NEGLIGIBLE      - .032          NEGLIGIBLE      NEGLIGIBLE
306008020    +     615030.      NEGLIGIBLE      + .012          NEGLIGIBLE      NEGLIGIBLE
             -     615030.      NEGLIGIBLE      - .012          NEGLIGIBLE      NEGLIGIBLE
306008030    +     615030.      NEGLIGIBLE      + .019          NEGLIGIBLE      NEGLIGIBLE
             -     615030.      NEGLIGIBLE      - .019          NEGLIGIBLE      NEGLIGIBLE
306008040    +     615030.      NEGLIGIBLE      + .005          NEGLIGIBLE      NEGLIGIBLE
             -     615030.      NEGLIGIBLE      - .005          NEGLIGIBLE      NEGLIGIBLE
306008050    +     615030.      NEGLIGIBLE      + .011          NEGLIGIBLE      NEGLIGIBLE
             -     615030.      NEGLIGIBLE      - .011          NEGLIGIBLE      NEGLIGIBLE
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Table 5-3-b. 1980 PETROLEUM INDUSTRY UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, PETROLEUM INDUSTRY                PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1980        RUN DATE=JUNE 24,1976
 MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC             CO          PART
306012000    +       11998.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     +  .004
             -       11998.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     -  .004

306012010    +       11998.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     +  .004
             -       11998.     NEGLIGIBLE     NEGLIGIBLE     NEGLIGIBLE     -  .004
```

regulatory impacts, economic considerations, and other matters. Development of emission factors for the more important SCCs was primarily based upon data provided in Ref. 5-1. The major sources of petroleum refinery emissions stem from combustion-generated emissions resulting from process heating and catalyst regeneration, while HC discharges result mainly from sources of leakage or evaporation.

In certain instances, revisions of CO factors were made for consistency with other firing equipment using similar fuels or known data. For example, the CO emission factor for oil-fired process heaters in SCC 3-06-001-01 is indicated as zero. The corresponding CO emission factor for external combustion boilers (SCC 1-02-004-xx and 1-02-005-xx) indicates 4-lb CO/1000 gal burned, which is equivalent to 168 lb/1000 bbl. The factor used in this instance was accordingly taken as 170 for equipment in this SCC.

In a similar way, it can be determined that CO variation in fluid catalytic cracking introduces uncertainty in the emission factor for SCC 3-06-002-01. The factor given for this effluent in Ref. 5-1 is 13,700-lb CO/SCC. Coke formation ranges between 4 and 10 percent of fresh feed charge. The amount of CO produced varies with the stoichiometry within the regenerator, but a range may be assessed in a simple way by assuming that the CO_2/CO ratio in the off gases is 1.5, which is typical (Ref. 5-2). On the basis of an 8 percent coke formation and a feed gravity of 300 lb/bbl, we have

$$5C + 4O_2 = 2CO + 3CO_2$$

$$\frac{\text{8-lb coke}}{\text{100-lb fresh feed}} \times \frac{\text{56-lb CO}}{\text{60-lb coke}} \times \frac{\text{300 lb}}{\text{bbl}} \times \frac{\text{1000 bbl}}{\text{SCC}} = \text{22,400-lb CO/SCC}$$

Slightly different assumptions can be made to show even more severe emission factors, which merely makes the uncertainty range greater.

5.4 GENERAL REFINERY STATISTICS

Statistical data from several data sources served as the basis for obtaining detailed information concerning crude charging rates, production capacities, product yields, and past production trends. Most refiners try to maximize gasoline and fuel production, although some operators concentrate on other specialty products as well. Average yields and other statistics of U.S. refineries are periodically published by the American Petroleum Institute (API) and also in industry journals such as The Oil and Gas Journal (Ref. 5-3). Percentage yields of various petroleum products for 1973 are represented in Table 5-4. As shown, gasoline represents the major product of the industry; the yield of gasoline relative to crude input is nearly one-half the total volume. This is a composite statistic; some refiners can obtain gasoline yields in excess of 60 percent.

Petroleum refinery statistics dating back to 1956 are given in Ref. 5-2. Few changes in refinery yields have occurred. Average gasoline yields have increased from 43.4 to 45.6 percent. The annual growth rate in crude runs to stills for the entire time period of Ref. 5-2 is 2.7 percent and 3.6 percent over the last 10 years. Gasoline production growth over this same time period has been nearly 4 percent and approximately 3 percent over the entire time period. Thus, refiners have been concentrating their efforts on producing ever increasing amounts of gasoline from crude. The most recent estimates for gasoline production in 1974 is about 6.5×10^6 bbl/day or nearly 10^{11} gal/year. Although kerosene production in Ref. 5-4 appears to have declined, it has been replaced by jet fuels. Total kerosenes therefore, are increased. A considerable decline in residual fuel oil yield from 14.7 percent in 1956 to 7.7 percent in 1973 is indicative of further processing of these "heavy ends."

Recent data on a state-by-state basis show that in early 1974 there were 247 refineries operating in the United States, with a daily stream crude capacity of 14.9×10^6 bbl/day, running at 96 percent capacity (Ref. 5-3). For 1975, the daily runs were estimated at 15×10^6 bbl, which when annualized on 350 days results in 5.25×10^9 bbl. Although this appears to be an

Table 5-4. 1973 DISTRIBUTION OF PETROLEUM PRODUCTS

Product	Percent of Refinery Yield
Gasoline	45.61
Distillate Fuel Oil	22.46
Residual Fuel Oil	7.74
Jet Fuel (Kerosene)	5.41
Kerosene	1.73
Jet Fuel (Naphtha)	1.44
Lubricants	1.50
Other	14.11

exceptional rise in the two-year interim following the last tabulated values of Ref. 5-2, it seems in line with present market demand patterns and industry construction.

A number of reference sources can be cited in forecasting energy demands, sources of supply, or projected growth rate of U.S. consumption (Refs. 5-5 through 5-11). Such issues as economics and industrial activity, population growth, domestic government policies, and related international politics lead to considerable uncertainty in forecasts. In this study, considering an overall oil requirement in the vicinity of 22 to 23 million bbl/day by 1980, refinery runs have been estimated to be in the range of 17 to 18.5 million bbl/day. On an annual charge rate basis, the values are from 6.0×10^9 to 6.3×10^9 bbl/year. When a SCC is measured in terms of 1000 bbl/year, these figures represent projected levels of 6.0 to 6.3×10^6 SCC/year and compare favorably with the long-term and recent-term trends discussed earlier.

5.5 PETROLEUM REFINERY PROCESSES EVALUATED

5.5.1 Process Heaters

Energy consumption requirements of typical refineries were determined to establish the emissions from combustion equipment. Energy used in refining, as in other industrial practices, is governed by fuel price. Nelson (Ref. 5-12) has shown that, for an average refinery, net energy consumption varies with refinery complexity, but for many years has generally remained in the range of 10 to 12 percent of processed crude. Newer refineries tend to have lower energy consumption because refiners have installed more efficient systems, enabling better overall heat utilization. In this study, the net energy consumption level was therefore assumed as 10 percent of 0.63×10^6 Btu/bbl oil processed. About two thirds of this heat is obtained in some plants by the burning of refinery process gases and about one third from the firing of salable liquids or residual fuel (Ref. 5-13). A further breakdown of process heater firing was obtained from a NEDS data tape printout which showed that 92 percent of the oil-fired process heater charge rate is in SCC category 3-06-001-01 versus 8 percent in SCC 3-06-001-03 (Ref. 5-14).

In forecasting to 1980, it was assumed that refineries will continue to increase in complexity (as they have for many years). There are several reasons why this should occur. A large portion of the industry lacks the capability to process high-sulfur crude oil (Ref. 5-15). Therefore, the industry will develop the flexibility to handle such crudes and at the same time will be upgrading production facilities to meet new environmental demands for pollution control and to produce lead-free and low-lead gasoline products. These factors will tend to be offset by certain energy conservation measures; hence, it was assumed that the energy required to operate refineries in 1980 will still be 10 percent of the total product processed by these refineries.

The overall energy consumed by oil-fired heaters will tend to decline as fuel-firing strategies will tend toward selection and use of process gaseous fuels having a low sulfur content. This is dictated by recently promulgated regulations (Refs. 5-16 and 5-17) which limit atmospheric sulfuric oxide (SO_2) emissions from process heaters. It has been estimated that a reduction of up to 30 percent of current energy values in SCC 3-06-001-01 can be realized. The implication of this is that future needs for process heat from this SCC will consume only about 25 percent of refinery fuel requirements, with greater implementation of refinery-process gas-fired equipment. At the same time, improved firing techniques will enable reductions in NO_x emission factors.

5.5.2 Fluid Catalytic Cracking

The fluid catalytic cracking capacity of an average refinery is about 30 percent of crude capacity, with larger companies tending to have higher fractions (approximately 34 percent) and smaller companies having lower fractions (24 percent)(Ref. 5-15). The largest fluid catalytic cracking plants operate in the range of 120,000 bbl/day, and there are eight plants of this size range (Ref. 5-3). The total annual charge rate of this SCC is presently 1.5×10^9 bbl/year. Over the past few years, the growth trend has been a fairly consistent 2.4 percent annually, so that by 1980 the expected new additions will account for 1.69×10^9 bbl/year, if no perturbations occur. According to Conn (Ref. 5-18), the attributes of fluid catalytic cracking are that fluid crackers (1) may be constructed in very large sizes, (2) are relatively free of mechanical problems, and (3) have proven flexible in operation.

As mentioned, several important advances have taken place in fluid catalytic cracking. These include improved catalysts and improved operating and regeneration techniques (such as riser cracking and two-stage regeneration) resulting in improved capacities and yields (Ref. 5-19), lower coke make, and lower emissions (Ref. 5-20). The rising trend in fluid cracking capacity is expected to continue.

However, the new standards of performance which became effective in 1974 limit the emissions from fluid catalytic crackers (Ref. 5-16). The promulgated standards apply to PART and CO emissions from new or modified catalyst regenerators. Essentially, an operator is prohibited from discharging (1) PART matter in excess of 1 kg/1000 kg (1 lb/1000 lb) of coke burnoff in the catalyst regenerator and (2) gases which contain CO in excess of 0.050 percent by volume (500 parts per million).

Background information contained in Refs. 5-21 and 5-22 shows that compliance with the new standards may be achieved by use of more than one type of control technique. Emissions of CO from fluid cracking regenerators are also discussed in Ref. 5-20.

Since the regulations apply to new plants and existing plants which were modified in a way that increased their emissions, it became necessary to assess the expected degree of modernization which can occur between the present and 1980. In other words, to forecast the emissions one must evaluate the expected rapidity of plant replacement and the fraction of controlled emission production levels which would be in effect by 1980. Information concerning refinery abandonments, replacements, enlargement, and modernization is scarce. As reported by Nelson (Ref. 5-23), a refinery that is to operate profitably must adhere to certain rules:

a. Grow in crude capacity so that the refiner retains his share of the growing market

b. Be constantly repaired and maintained

c. Grow in downstream technology to meet product and quality requirements

d. Grow technologically so that it remains competitive

Thus, not only does crude and downstream capacity increase, but whole process units (e.g., crude, cracking, and reforming) are replaced from time to time so that the larger refinery is not simply an accumulation of small units. It has also been shown that on average a refinery can be kept competitive with respect to crude capacity and downstream facilities by doubling every 12 to 13 years, or at an annual rate of 5.7 percent. In addition, during recent years, now operating refineries of major companies have been below 0.4 percent of existing capacity. The approach taken was to assume that these criteria apply also to fluid catalytic cracking, and on this basis an analytical assessment was made on 1980 charge rates.

5.5.3 Moving Bed Cracking

This form of catalytic cracking appears to be of diminishing importance in terms of overall charge rates. Recent trends according to Ref. 5-15 show that daily capacity receded from 0.5×10^6 bbl/day in 1972 to 0.3×10^6 bbl/day in 1975. At this rate of decline (roughly 16 percent annually), the daily charge rate would be about 0.13×10^6 bbl/day, but it is not known how the new regulations will affect refiners plans. The approach used was to assume the decline would continue at approximately half this rate so that by 1980 the daily throughput would be 0.2×10^6 bbl/day. The annual charge rate becomes 0.07×10^9 bbl/year or 0.07×10^6 SCC/year. The uncertainty in charge rate is thus relatively high. The emission factors used were those in Ref. 5-1.

5.5.4 Coking and Miscellaneous Categories

These categories include particulate dispersions resulting from coke making and various other HC losses. No special approach was necessary for SCCs based upon total annual charge rate. For coking, annual charge rates were based on the assumption that two percent of capacity is used in coke making. According to Ref. 5-3, coke capacity of 43,410 tons is obtained from a daily feed capacity of 14.2×10^6 bbl. At 300 lb/bbl, we obtain

$$\frac{43,410 \text{ ton/day}}{14.216 \times 10^6 \text{ bbl/day} \times 300 \text{ lb/bbl} \times \frac{\text{ton}}{2000 \text{ lb}}} \times 100 = 2.0\%$$

5.6 RESULTS AND DISCUSSION

Tables 5-2-a and 5-3-a summarize the results of the inventory studies for process heaters, catalytic cracking, and the miscellaneous categories of fluid coking and equipment leakage.

Emission factor levels are generally found to be declining gradually. This is expected to result from higher monetary values for fuel and more stringent control of emissions through expansion and modernization. The new ruling especially in regard to fluid catalytic cracking is estimated to affect 0.67×10^9 bbl/year of fresh feed charge rates out of a total of 1.69×10^9 bbl/year by 1980. In other words, of the current 1.5×10^9, nearly one third of the total charge will either have been replaced or modernized and will therefore be in compliance.

However, as seen in Tables 5-2-b and 5-3-b, large uncertainties can exist in charge rate data, emissions, and other data. It is therefore necessary to periodically review industry production trends, technology achievements, and consumer demands which can impact the resulting year-to-year data.

It was originally intended to compare emission level results from the NEDS data. However, because of significant discrepancies found in the past, this was not attempted here. The most recent NEDS data error showed that total annual charge rate in fluid catalytic cracking was approximately a factor of 20 too high (Ref. 5-4). This error was acknowledged and corrected in Ref. 5-24.

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APPENDIX 5.A

DISCUSSION OF PETROLEUM REFINERY PRACTICES

5.A.1 BACKGROUND

Familiarization with overall refinery technology (Ref. 5.A-1) is prerequisite to understanding the refinery industry practices which constitute important sources of atmospheric emissions. The raw feedstocks, consisting mainly of crude oil but including, also, natural gas and asphalt, are subjected to thermal or chemical treatments leading to a broad variety of intermediate and finished products.

A single refinery may not produce all petroleum products, even in the most diverse of the major composite refineries. Significant differences occur in chemical composition and physical properties of the crude liquid feedstocks that are available to an individual plant. For example, some crudes are highly amenable to the economical production of lubricants and waxes, whereas others may be less so. The fundamental determinant defining which products will be produced at a given refinery is economics. Economics includes not only such factors as equipment capitalization, operating costs, and product values, but also feedstock costs and variability.

5.A.2 REFINERY PROCESSING OVERVIEW

It is desirable to recognize certain types of similar refinery processes and operations from a chemical engineering aspect. The more important manufacturing procedures that may be associated with atmospheric emissions are identified as follows:

a. Topping
b. Crude distillation
c. Gasoline stabilization
d. Vacuum flash operation
e. Cracking (thermal and catalytic)
f. Catalytic reforming
g. Hydroprocessing
h. Alkylation
i. Isomerization

5.A.2.1 Topping

The basic operation in all refineries is atmospheric pressure distillation. This operation, known as topping, represents the first step in the fractionation of crude oil feedstock into various boiling range components such as gasoline, kerosene, distillates, lubricants, and fuels. Crude-oil distillation normally requires preheating the feedstock in a heat exchanger train and/or direct-fired heaters before being fed to the distillation tower units. The overhead stream condensate (raw straight-run gasoline) goes to a stabilizer column for propane-butane removal, yielding stabilized straight-run gasoline for later treatment and octane upgrading. The side streams, which boil at intermediate temperatures, yield naphtha, kerosene, diesel oil, and gas oil. The bottom stream, also called reduced crude, may be vacuum-fractionated for lube manufacture or run (with gas oil) into cracking units for conversion into lower molecular weight products, particularly gasoline.

5.A.2.2 Cracking

The major forms of cracking are thermal and catalytic processes. At one time during World War II, overall gasoline yield from crude was less than 40 percent, and thermal cracking accounted for more than 20 percent of total gasoline yield from crude. Thermal processes are now mainly used for viscosity breaking (visbreaking) of reduced crudes and for coke production. Catalytic cracking is used mostly with gas oil but may sometimes be used on various fractions, including naphtha and residuals. The process takes one of several forms, depending upon the method of handling the catalyst. Fluidized bed catalytic cracking represents the largest overall capacity in the United States, followed by Thermofor and Houdriflow moving bed processes. Cracking causes decomposition of the higher molecular weight constituents of petroleum, which produces products in lower boiling ranges. These include large amounts of olefinic gases, gasoline, and recycle oil. Coincident with the disintegration mechanisms, coke deposits on the catalyst. The amount and rate of coke formation varies with the type of feed and catalyst, system design, and operating conditions. Generally, the coking laydown ranges between 4 and 10 percent of the fresh feed charge (Ref. 5.A-1).

Since catalyst activity declines with coke deposition, reactivation is required and is accomplished by periodic burnoff of the coke with air. Modern systems operate continuously by recirculating finely divided catalyst beads between the reactor and the regenerator. Regenerator off gases contain the usual combustion products of HC, but complete combustion of carbon is seldom accomplished during regeneration. Concentrations of CO in the flue gases, therefore, are also variable but generally 8 to 10 percent by volume. Further combustion of these gases in flares or CO boilers may be accomplished to recover heat energy and to minimize emissions. Cyclone separators are the means used to retain the solids in the circulating system. Additional separation equipment in the form of electrostatic precipitators can be used to further recover catalyst fines.

Recent advances have occurred in fluid catalytic cracking, including the use of highly active zeolitic catalysts, higher pressures and temperatures, more efficient equipment, and improved construction materials. Higher equipment capacities, improved conversion and energy utilization, higher octane products, and greater operating flexibility have resulted. Descriptions of several modern catalytic cracking processes as practiced by major refiners are provided in Ref. 5.A-2. Considerable study effort was devoted to catalytic cracking practices because of the overall impact of these practices on atmospheric emissions.

5.A.2.3 Catalytic Reforming

Catalytic reforming causes rearrangement of HC molecules, primarily accompanied by hydrogen abstraction (dehydrogenation) or addition (hydrogenation). The process is used to upgrade low-octane naphtha to high-octane gasolines and to produce aromatics such as benzene, toluene, and xylene (BTX). Reforming was developed in the late 1940s and early 1950s with a platinum catalyst on a ceramic substrate. One of the main advantages of the so-called platforming process at that time was the great improvement in catalyst lifetime relative to existing cracking catalysts. In catalytic cracking, about 10-gal oil/lb catalyst could be processed before regeneration was needed while the reforming processes could treat 1000-gal oil/lb catalyst. By 1956, as much as 10,000-gal oil/lb catalyst could be treated. Other advantages of reforming included resistance to permanent catalyst poisoning, ability to achieve multiple reactions simultaneously (e.g., dehydrogenation, dehydroisomerization, dehydrocyclization, isomerization, and hydrodesulfurization). In short, the process was used to produce a high quality gasoline known as reformate and a high yield of aromatics (for which there existed a high market demand at the time). More recently, catalytic reforming processes have become a valuable source of byproduct hydrogen. As in the case of catalytic cracking, newer catalysts (some including nonnoble materials) are being developed. The processes are variously referred to as platforming, magnaforming, houdriforming, powerforming, rheniforming, and ultraforming (Ref. 5.A-2).

A particular type of reforming process involving rearrangement of a HC molecular structure is known as isomerization. Originally, isomerization involved the vapor-phase conversion of HC from one structure to another by an acid catalyst (e.g., butane to isobutane, C_4 isomerization; pentane to isopentanes, C_5 isomerization). Now, more modern plants such as Butamer, Penex, and Hysomer process reactants in the presence of highly active and selective fixed-bed noble catalysts. Such plants are often operated in conjunction with alkylation facilities. The clear octane ratings of isomerization products is significantly improved. Unconverted reactants are often recycled.

5.A.2.4 Hydroprocessing

The rapid increase in catalytic reforming capacity during the past 25 years and the consequent availability of large amounts of hydrogen produced therefrom has stimulated the development of refinery processing in which the low-cost hydrogen is consumed or used within a particular process. The general terms hydroprocessing, hydrotreating, and hydrorefining are used to describe a multitude of production systems. The most usual applications are for desulfurization (also called hydrosulfurization) of various petroleum fractions in which many of the more stable sulfur-containing compounds, such as mercaptans, are destroyed catalytically into HC remnants. The liberated sulfur combines with the hydrogen to form hydrogen sulfide gas which requires removal to avoid emission to the atmosphere. This may be accomplished in several ways, often leading to recovery of marketable byproduct sulfur compounds.

Some of the more commonly known processes are Gulfining, HDS, RDS, VRDS, and ultrasweetening. Besides desulfurization treatments, hydrogen processing includes selective hydrogenation treatment of certain olefin or aromatic stocks and lube oil improvement. Finally, there are combination processes such as ultrafining. A number of hydroprocessing plant descriptions are contained in Ref. 5.A-2.

5.A.2.5 Rebuilding Processes

Several processes are used to rebuild various types of low molecular weight of hydrocarbons into higher molecular weight species. Alkylation and polymerization are processes in which unsaturated two-, three-, and four-carbon atom gases are reacted in order to form high-octane branched chain hydrocarbons for gasoline. The olefinic feedstocks are usually cuts obtained from catalytic cracking. When olefins are added to olefins, the product is called polymer gasoline. When an olefin is connected to a saturated molecule such as isobutane, the product is called alkylate. Alkylate finds extensive use in aviation gasoline.

5.A.2.6 Other Processes

Several other refinery processes were examined but do not appear at this time to be significant factors relating to atmospheric emissions in terms of volatile HC, CO, CO_2, or NO_x except, perhaps, from the standpoint of requiring boiler-produced steam or direct-fired thermal energy. These include the following:

a. Light oil treating
b. Lube oil processing
c. Asphalt manufacture
d. Sulfur recovery
e. Wax forming operations

Coking processes involve relatively severe cracking for converting heavy components (such as pitch and tar) into lighter products (such as gas oil and coke) for fuel and other specialty uses. Two major processes are delayed coking and fluid coking, the latter being a continuous fluidized bed circulation flow process. In withdrawing the coke product from the system, some entrainment of particulates does occur as the gases pass through the cyclone separators and disperse to the atmosphere.

5.A.3 REFERENCES

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CONVERSION FACTORS

To Convert From	To	Multiply By
Barrel (42 gallons)	Cubic meters	1.590×10^{-1}
British thermal unit	Joules	1.055×10^{3}
Fahrenheit (temperature)	Kelvin	$T_K = \frac{5}{9}(T_F + 459.67)$
foot	Meters	3.048×10^{-1}[a]
gallon (U.S. liquid)	Cubic meters	3.785×10^{-3}
horsepower $\left(550 \frac{\text{ft-lbs}}{\text{sec}}\right)$	Watts	7.457×10^{2}
inch	Meters	2.54×10^{-2}[a]
lb_f (pound force)	Newtons	4.448×10^{0}
lb_m (pound mass)	Kilograms	4.536×10^{-1}
Ton (short, 2000 pounds)	Kilograms	9.072×10^{-2}
lb_m per gallon	Kilogram per cubic meters	1.198×10^{2}
Cubic feet	Cubic meters	2.832×10^{-2}
lb_m per cubic foot	Kilograms per cubic meter	1.602×10^{1}
Btu per ton	Joules per kilogram	1.163×10^{0}
Btu per gallon	Joules per cubic meter	2.787×10^{5}
Btu per cubic foot	Joules per cubic meter	3.726×10^{4}

[a] Exact.

GLOSSARY

ACR	annual charge rate
API	American Petroleum Institute
bhp	brake horsepower
BTX	benzene, toluene, xylene
CO	carbon monoxide
EEI	Edison Electric Institute
EPA	Environmental Protection Agency
H_2	hydrogen
HC	hydrocarbons
IC	internal combustion
KPPH	thousands of pounds per hour
MMBtu/hr	millions of British thermal units per hour
MSCC	modified source classification code
N	nitrogen
NEC	not elsewhere classified
NEDS	National Emissions Data System
nm	nanometer (formerly millimicron)
NH_3	ammonia
NO_x	oxides of nitrogen

PART	particulate matter
PPM	parts per million
SCC	source classification code (NEDS)
SIC	standard industrial classification
SO_2	sulfur dioxide
TACRP	total annual charge rate projected
T_F	temperature, degree Fahrenheit
T_k	temperature, Kelvin